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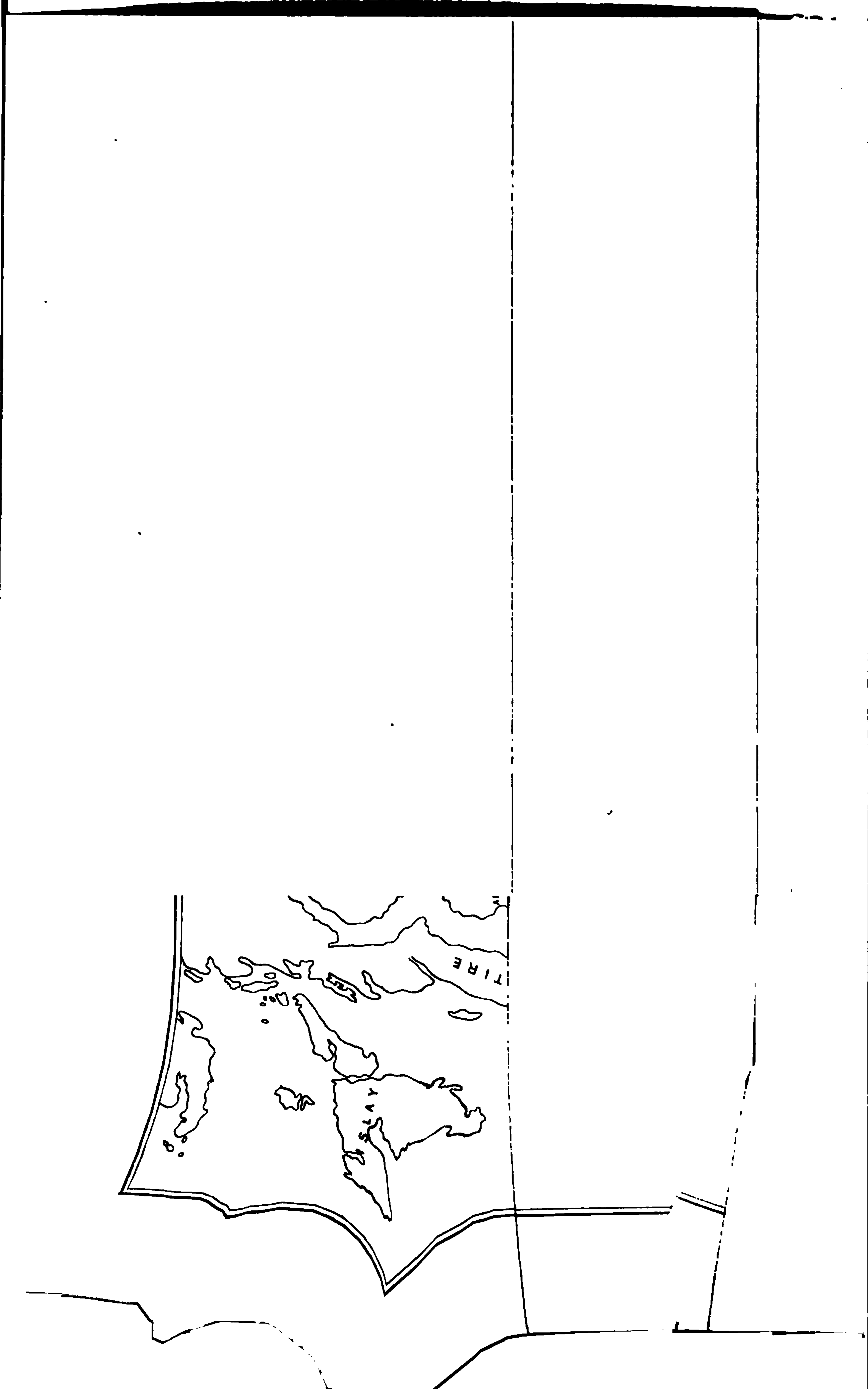
THE

COAL AND IRON INDUSTRIES

OF THE

UNITED KINGDOM.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THE

COAL AND IRON INDUSTRIES

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UNITED KINGDOM.

COMPRISING

A DESCRIPTION OF THE COAL-FIELDS, AND OF THE PRINCIPAL SEAMS OF COAL, WITH RETURNS OF THEIR PRODUCE AND ITS DISTRIBUTION, AND ANALYSES OF SPECIAL VARIETIES.

ALSO

AN ACCOUNT OF THE OCCURRENCE OF IRON ORES IN VEINS OR SEAMS; ANALYSES OF EACH VARIETY; AND A HISTORY OF THE RISE AND PROGRESS OF PIG IRON MANUFACTURE SINCE THE YEAR 1740, EXHIBITING THE ECONOMIES INTRODUCED IN THE BLAST FURNACES FOR ITS PRODUCTION AND IMPROVEMENT.

BY

RICHARD MEADE,

ASSISTANT KEEPER OF MINING RECORDS.

WITH MAPS OF THE COAL-FIELDS AND IRONSTONE DEPOSITS OF THE UNITED KINGDOM.

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PREFACE.

NUMEROUS inquiries made on matters connected with our Iron and Coal Industries led me in the year 1874 to prepare a series of articles on iron for the "Mining Journal." These articles were favourably received, and I was strongly urged from various quarters at home and abroad to publish the information in a more extended form.

It had previously occurred to me that, although much valuable information existed on these subjects, it was too widely diffused to be practically useful.

My aim, therefore, has been to condense all available information, and to introduce into this volume such details relating to our coal, iron and steel industries as were available. These may be briefly enumerated as follows—the coal-fields, their extent and area, the principal coal seams and ironstone measures, the production and distribution of the coal and ironstone; the variations in prices, the population employed under and above ground, and considerations as to the probable duration of the coal deposits.

In carrying this out, the early history of the rise and

progress of pig-iron manufacture has been traced since the year 1740, each iron-making district being separately considered, and the production recorded. The quantities of coal and iron ore used in this important manufacture have been given, and the returns bearing upon economy in the use of coal in the smelting operations of the blast furnace have been carefully collected and stated. Lists of all the works engaged in the manufacture of steel by the Bessemer, Siemens, Siemens-Martins, and Thomas-Gilchrist processes have been included.

I have spared no labour in consulting every authority within reach, and I believe much valuable matter—throwing considerable light upon the manufacture of pig-iron towards the end of the last and beginning of the present century—has been obtained.

Amongst others the annual Reports of H.M. Inspectors of Mines, the Reports of the Royal Coal Commission in 1870, and the select Committee of the House of Commons in 1873, appointed to inquire into the "Cause of the dearness of Coal," have furnished much information. The consumption of fuel in the manufacture of pig-iron was first ascertained for the latter Committee, and has since then been published regularly in the annual volume of the "Mineral Statistics of the United Kingdom."

Having referred to the principal sources from which the details have been derived, it remains for me to express my obligations to all who have aided me in my labour. To the officers of the Geological Survey I owe many

obligations, particularly Mr. Frank Rutley, F.G.S., who kindly favoured me with the introductory chapter on "The Mineralogical Character of the principal Iron Ores." To my colleague Mr. James B. Jordan, I am indebted for the map to illustrate the coal and iron districts of the United Kingdom. To the proprietors of the "Mining Journal," who courteously placed at my disposal my early papers published in that journal; and to many gentlemen whose names appear in the text as having rendered valuable assistance, I respectfully tender my sincere thanks.

NOTE.

It may be desirable to state, that throughout the first part of this volume the statistics referring to the "production of coal," have been derived from two sources of information. One of these sources is the series of "MINERAL STATISTICS OF THE UNITED KINGDOM," *issued annually from the Mining Record Office; the other the* "REPORTS OF H.M. INSPECTORS OF COAL MINES."

In considering the production of the several coal-fields, the "MINERAL STATISTICS" *have been used, inasmuch as the series extends over a longer period, and gives annual returns continuously since the year* 1854. *In computing the probable duration of our coal-fields, the same authority has been taken as a basis of calculation.*

With regard to the population employed in our coal-fields, and its relation to the amount of coal raised, and the average produce per man, the "REPORTS OF H.M. INSPECTORS OF MINES," *commencing with the year* 1864, *have been adopted, as relating more especially to these matters.*

R. M.

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THE

COAL AND IRON INDUSTRIES

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THE UNITED KINGDOM.

PART I.

COAL INDUSTRIES.

MAP OF IRELAND.
Shewing the areas of
COAL FIELDS
and position of the principal
IRON ORE WORKINGS
IN
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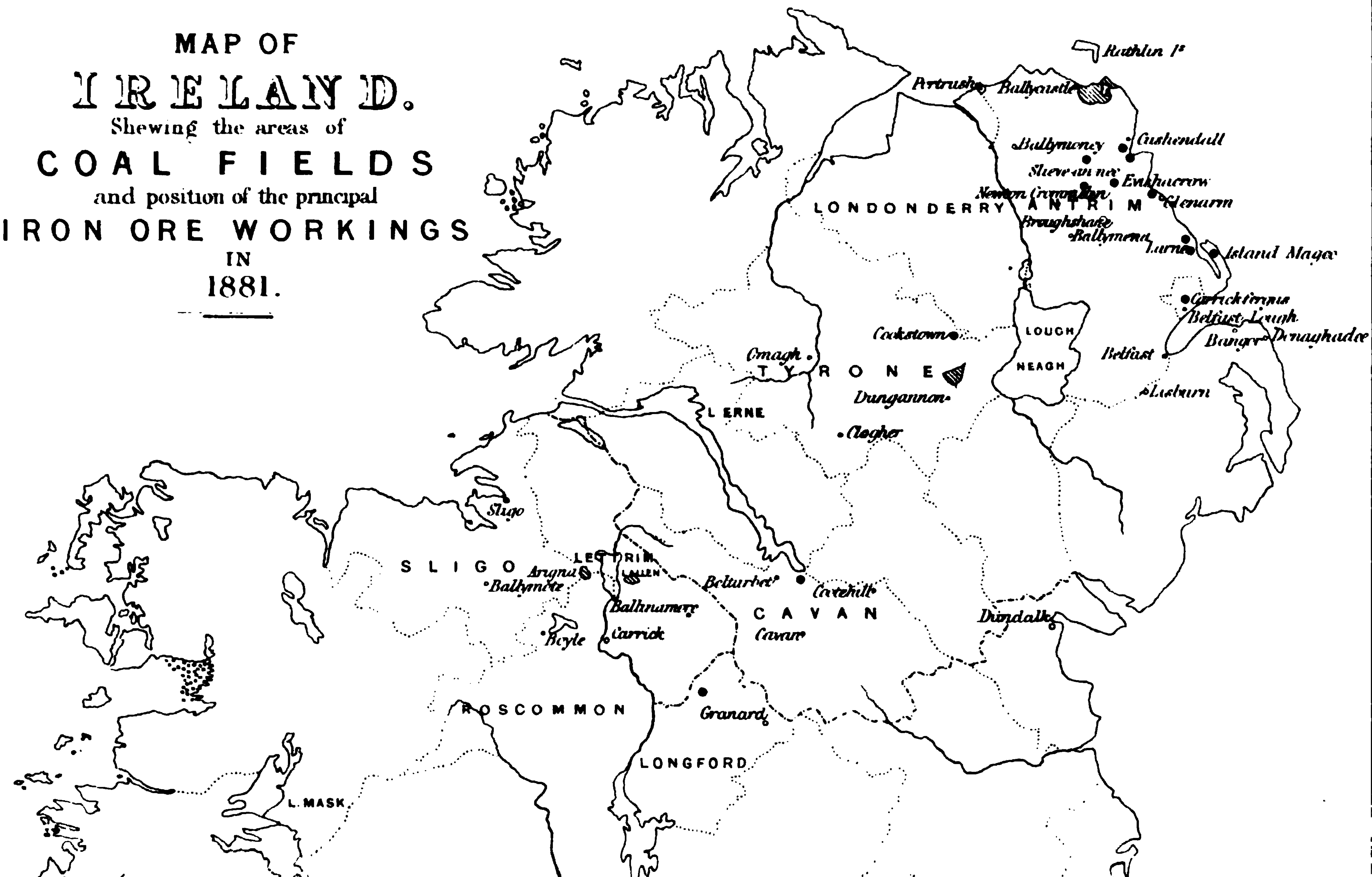

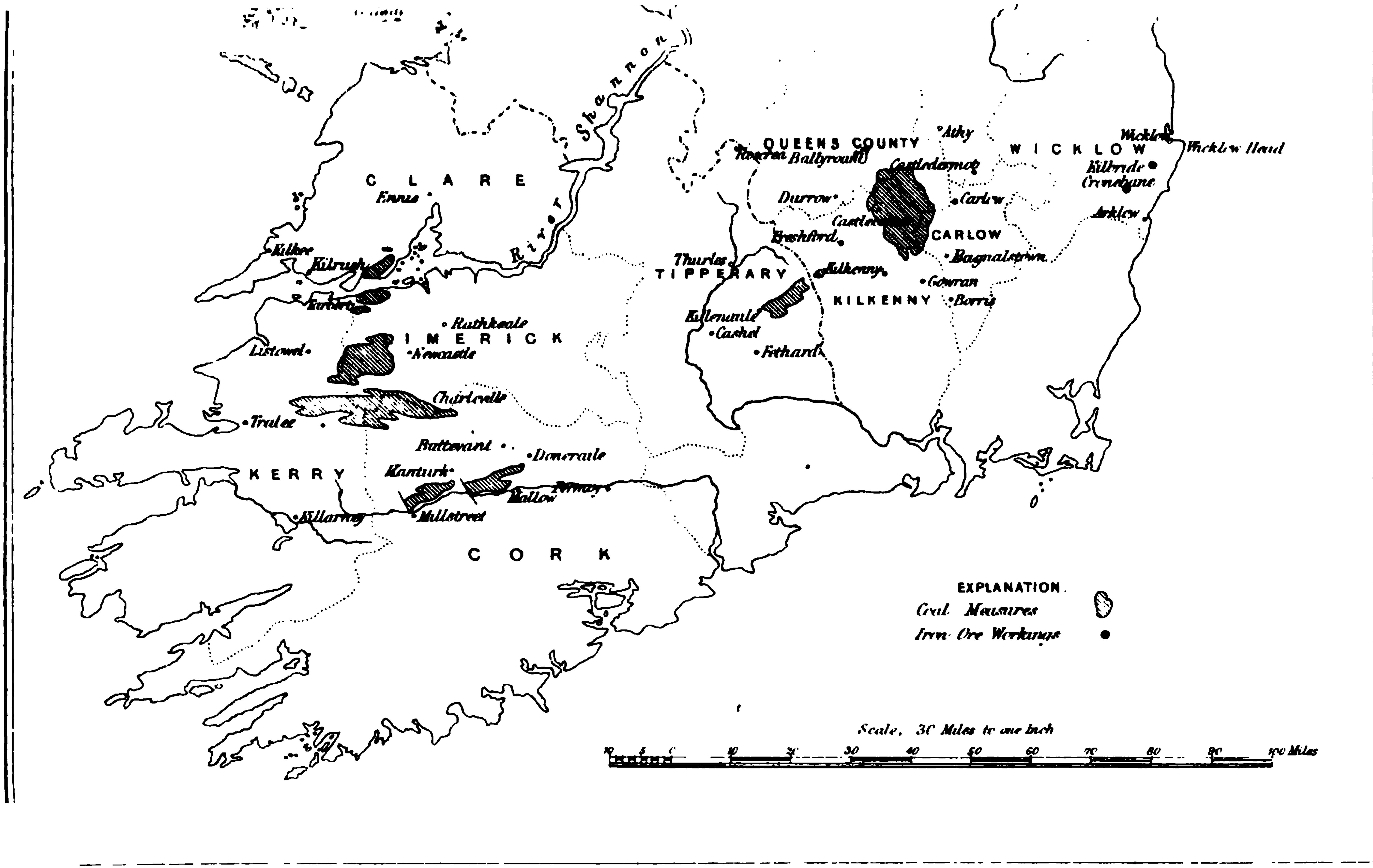

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THE

COAL AND IRON INDUSTRIES

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PART I.

COAL INDUSTRIES.

CHAPTER I.

THE DURHAM AND NORTHUMBERLAND (OR GREAT NORTHERN) COAL-FIELD.

Early History of the Coal-field—Extent, Area, and Geological Features of Coal-field—Varieties of Coal and Analyses—Production and Distribution of Coal by Railway and Sea—Prices and Cost of Production—Population employed in Coal Mining—Resources and probable Duration of Coal-field.

Early History of the Great Northern Coal-field.—The early history of this coal-field presents numerous and interesting features, and extends to a remote period; a few of the more general facts may be referred to. As early as the year A.D. 852 there is a record of the Abbey of Peterboro' receiving twelve cart-loads of fossil or pit coal. In 1180 there occurs, in Bishop Pudsey's book (Bishop of Durham), a grant of land to a collier, for providing coals for the cartsmith at Coundon, in the County of Durham; similar grants being made at Bishopwearmouth and Sedgefield in the same county.

Again, in the reign of Henry III., A.D. 1239, a charter was granted to the freemen of Newcastle-upon-Tyne to dig coals in the castle fields, and it appears that it was about this time that coal was first sent to London. About the end of Edward I.'s reign, A.D. 1305, considerable quantities of coal were used by

brewers and smiths; this was followed by numerous complaints being made of the injurious effects of the smoke; the burning of coal was prohibited, and by commission from the King fines levied to prevent it. Nothing appears to have resulted from this prohibition, as coals are stated to have been used a few years later at the King's coronation. In Edward III.'s time a licence was granted to the freemen of Newcastle-upon-Tyne to work coals within the town walls; and about A.D. 1367 coals were also worked in the neighbourhood of Winlaton, near Newcastle-upon-Tyne.

The first government tax was laid upon coals in the year 1379; in 1421 a duty of twopence per chaldron was paid to the Crown "on all coals sold to persons not franchised in the port of Newcastle." This duty having got into arrear, payment was demanded by Queen Elizabeth, and in lieu of arrears a duty of one shilling per chaldron was imposed, which was enforced to the time of Charles II., when it was settled on his natural son the Duke of Richmond. In 1799 the Government of the period purchased the above tax for an annuity of £19,000; this was ultimately repealed in 1831, the tax having been in operation upwards of four centuries in the neighbourhood of the Tyne.

Queen Elizabeth imposed a tax of five shillings per chaldron on coals sent over sea, to which King James I. added three shillings and fourpence per chaldron, and an additional one shilling and eightpence per chaldron on coals exported in foreign ships. After the great fire of London, the Lord Mayor was granted an impost of one shilling per chaldron for rebuilding the City; this was further increased to three shillings per chaldron. In the year 1670 an additional tax of two shillings per chaldron was imposed by Parliament, for the purpose of rebuilding fifty-two parish churches, and in 1677 a further tax of three shillings per chaldron was imposed, partly for rebuilding St. Paul's Cathedral. These duties for rebuilding churches continued during the reign of Queen Anne.

The duties on coal during the eighteenth century varied considerably, being at one time as high as nine shillings and fourpence per chaldron; these duties however have, except the City of London tax on coals of one shilling and one penny per ton, long since been repealed.

The export duty on coals to foreign countries was wholly repealed, by the Act 13 & 14 Vict. c. 95, from 14th August, 1850.

Previous to this period the duties levied on coal, cinders and culm exported from the United Kingdom was three shillings and fourpence per ton in British ships, and six shillings and eightpence per ton in foreign ships, the duties on small coal, &c., being respectively two shillings per ton in British, and four shillings per ton in foreign ships.

The Great Northern, or Durham and Northumberland Coal-field.—This extensive area, comprising an exposed coal-field of 460 square miles and a concealed area of 225 square miles, possesses some of the most important coal-seams wrought in Great Britain. The rivers Blythe, Tyne and Wear naturally give names to the three great divisions of the coal-field. The Blythe coal-field, the Tyne coal-field, and the Wear coal-field are really one, extending from near Warkworth at the mouth of the river Coquet on the north, to near the north bank of the Tees (within 6 miles of Barnard Castle) on the south—a distance of nearly fifty miles in length, by twenty miles in breadth; its greatest diameter being near the centre, along the course of the river Tyne, narrowing in the north after passing the river Blythe. Beyond the exposed and concealed coal-fields above referred to, embracing an area of 685 square miles, there is, extending under the German Ocean, another area of 111 square miles known to be available.

From the Coquet near Warkworth to the river Tyne, the German Ocean limits the coal-field to the east; the Permian rocks then overlie the coal measures, forming an escarpment of magnesian limestone which ranges to the southward. As far south as Hartlepool the sea-cliffs are of magnesian limestone; beyond this is lower land formed of Triassic rocks. The southern boundary of the coal measures will probably be found to occur a little north of Hartlepool, and will from thence range south-westwards to a little north of Bishop Auckland. "The centre of the basin is on a line beneath the North Seaton Colliery and Jarrow. South of the Tyne the axis of the basin passes under the Permian rocks and the magnesian limestone in a line from Jarrow to Monkwearmouth Colliery, which is supposed to be the bottom of the basin. The beds there are nearly flat; they are supposed to rise on all sides." * The eastern limit of the coal basin will therefore be well out to sea under the German Ocean.

The coal measures of the northern coal-field are about 2,000

* Mr. H. H. Howell. Report of Royal Coal Commission, vol. i., p. 139.

feet in thickness. Those which contain the workable seams probably represent the "Middle Coal Measures" of more southern districts. The "Lower Coal Measures," or Gannister Beds, contain only thin seams; this division cannot be identified in the northern part of the coal-field. It is not certain which part of the series, if any, represents the "Upper Coal Measures." Professor Hull takes the "High Main" as the top of the Middle Coal Measures; this line of division is useful as marking off the more important seams, those lying above the High Main being comparatively unimportant.

The most important seams are the High Main and the Low Main; they are usually separated by about 60 fathoms of strata, in which several other seams occur. As a rough guide and aid to memory it may be useful to note that in Northumberland the following seams, which are some of the most constant in the coal-field, are separated from each other by about 30 fathoms of strata:—

Seventy-fathom or Black Close Seam.	Low Main.
High Main.	Beaumont, or Harvey.
Yard Seam.	Brockwell.

The following section by Professor Hull, F.R.S., indicates the position, thickness, and order of occurrence of the coal-seams in the Newcastle district.*

COAL SERIES OF NORTHUMBERLAND AND DURHAM.
(NEWCASTLE DISTRICT.)

		Ft.	In.
UPPER SERIES.	*Closing Hill Seam*	1	8
	Strata	450	0
	Hebburn Fell Seam	2	8
	Strata	250	0
	Five-quarter Seam	4	0
	Strata	260	0
	Three-quarter (Black Close) *Seam*	2	0
	Strata	50 to 180	0
1.	*High Main Coal*	6	0
	Strata	from 33 to 150	0

* "Coal Fields of Great Britain," 4th edition, p. 276.

COAL SERIES OF NORTHUMBERLAND AND DURHAM—*continued.*

		Ft.	In.
2. *Metal Coal*		1	6
Strata		33	0
3. *Stone Coal*		1	6
Strata	60 to	100	0
4. *Yard Coal* (variable)		2	10
Strata	60 to	100	0
5. *Bensham Coal*	2 ft. 5 in. to	5	0
Strata		78	0
6. *Five-quarter Coal*		3	0
Strata		48	0
7. *Low Main* or *Hutton Coal*		6	0
Strata	30 to	100	0
8. *Crow Coal* (inconstant)		2	10
Strata		24	0
9. *Five-quarter Coal*		3	8
Strata		30	0
10. *Ruler Coal*		1	10
Strata		96	0
11. *Townley* or *Harvey Coal*		3	1
Strata		42	0
12. *Jetty Coal*		2	2
Strata		42	0
13. *Stone Coal*		2	5
Strata		18	0
14. *Five-quarter Coal*		3	4
Strata		30	0
15. *Three-quarter Coal*		2	6
Strata		54	0
16. *Brockwell Coal*		2	11

The foregoing table applies chiefly to the neighbourhood of Newcastle and the districts to the west of that town. Slight variations and differences of names are met with in other districts, but this sufficiently describes the general succession. It is doubtful if the seams below the Low Main are of much value in the south-east of Northumberland and neighbouring parts of Durham. Boreholes put down to explore them at some collieries of late years have failed to prove the expected seams.

Most of the other important seams can be traced through the greater part of the coal-field, being known by various names in different parts. But on the north of the river Wansbeck there is some difficulty in recognizing the beds. Just north of the river the Low Main has been worked. The "Main Seam" of Ashington and Longhirst Collieries represents the "Grey Seam" (metal and stone coals), of other districts. But the relations of the seams in other collieries are somewhat uncertain.

It has long been the custom in this district to designate many seams by their thickness; thus, the "Yard Coal" is a coal which, where first chiefly worked, averaged a yard in thickness. Other seams are spoken of as so many parts of a yard; thus a "five-quarter seam" is a coal about 3 feet 9 inches thick. The seam most commonly known by this name is that next above the Low Main; but in the table three other seams have the same name.

The Northern coal-field is much intersected by faults, some of very great amount. In the immediate neighbourhood of these the beds often have a high dip, but through the greater part of the coal-field the seams lie at a gentle inclination. Besides the faults, or "slip troubles" of the miners, there are basaltic dykes known as "whin troubles."

In the western and northern parts of Northumberland a large quantity of coal is raised from seams in the carboniferous limestone series. The beds here are on the same geological horizon as the thick limestones of Derbyshire, but on going northwards we find the limestones to be gradually split up by shales and sandstones, until in Durham and Northumberland limestone forms but a small part of the whole.

In Northumberland there are a large number of coal seams worked in these lower beds. In the south of the county the "Little Limestone Coal," or Acomb seam, is the most important; in central Northumberland the Shilbottle seam; in the northern part of the county many seams are worked, the most important collieries being those near Scremerston.

Although as compared with the true coal measures the yield from the limestone district is small, yet taken together it comes to a considerable amount. In 1879 the total yield of the limestone coals in Durham and Northumberland was about 250,000 tons, the total production of the Great Northern coal-field being 29,552,079 tons.

Clay ironstone is not an important product of the Northern coal-field. It is found, however, in some places of sufficient thickness to have been worked. It usually occurs in thin beds in the shale, and contains large numbers of *Anthracosia;* hence it is usually known to the miners as "Mussel-band." The most constant portion of this bed is a little way above the Low Main seam; but occasionally there are shell beds, which sometimes contain ironstone, above other seams.

Clay ironstone in nodules in shale occurs sometimes in the limestone series. The most important horizon for this is below the "Four-fathom Limestone," as worked at Brinkburn and numerous places north of the Tyne; and at a much lower horizon, Ridsdale, Hareshaw, &c.

The coal-field of Northumberland and Durham is naturally divided into districts, which produce the following descriptions of coal: household fire coal, gas coal, manufacturing coal, steam coal, and coking coal.

Household Coal.—The household fire coal of these counties has ever been held in high repute. The celebrated "Wallsend" * was for a long period of years produced from the High Main Coal of the Tyne, the colliery from which it was produced being at Wallsend on the Tyne, and hence the origin of the designation "Wallsend" to distinguish the "Best Household Fire Coal." This coal was also produced at the various collieries of Percy Main, Walker, Heaton, Willington, &c., on the Tyne. It was not that coal of similar, or, indeed, as afterwards turned out, of superior quality, was not produced on the Wear and Tees, but the coal of such quality on the Wear being mixed with and sold with other coals of an inferior quality, no coal of that river, or, indeed, in the whole coal-field, bore such an excellent character, or sold at such high prices as the "Wallsends" of the Tyne. Time, however, arrived when the Hutton coal seam of the Wear (the Low Main of the Tyne district) was sold unmixed with other coal; and being found in the neighbourhood of Rainton, Lambton, and Hetton, of very superior quality, it was brought into the market as a Wallsend coal. The superior Wallsends of the Tyne being worked out, it took their place, and up to

* The name has since been given to several coals, which are not equal to the original.

the present time, has been sold as the best Wallsend coal. This coal is now produced from the Hutton seam of the neighbouring collieries of Stewart, Lambton, Hetton, and Haswell. The only coal for a long period on the Tees, approaching to the quality of the Wallsends of the Wear, was Tees Wallsend, or the Five-quarter and Main coal of the Black Boy Colliery, but more recently, the Five-quarter seam of the Hartlepool district has produced a coal approaching to the Wear Wallsends. Household fire coal of second quality is produced from the collieries of all the other localities.

The household coal of the Great Northern Coal-field has ever had a high reputation in the London market, where it is known as "seaborne coal;" it is largely imported, and commands a high price; it possesses great heating power, is steady and uniform in combustion, leaving but little residue and a small proportion of ash. A few analyses will illustrate the constituents of household coal, that of the Hutton seam being now the best variety in the district.

Constituents.	Haswell.	Hartley.	Original Hartley.
Carbon	83·47	84·284	81·18
Hydrogen	6·68	5·522	5·56
Nitrogen	1·42	2·075	0·72
Sulphur	·06	1·181	1·44
Oxygen	8·17	6·223	8·03
Ash	·20	0·715	3·07
	100·00	100·00	100·00

Gas Coal and Analyses.—The best gas coal in this district is produced from the Hutton seam, which also, as previously stated, produces the best household coal. It is, however, less compact, and liable to disintegration, and as such is not so well adapted for a first-class household coal. Consequently it is of less value for that purpose, but equally valuable as a gas coal. This variety of coal is obtained from the Felling, Pelaw, Pelton, and other collieries, and from some of the lower seams on the Tyne. It is also produced from the same seam on the Wear, and from the Brockwell seam on the Tees. Gas for illuminating purposes was originally introduced by Mr. Murdoch, an assistant of Mr. James Watt, who first lighted his office at Redruth, in Cornwall,

and used gas condensed in cylinders, as a light at night in going to the mines, about the year 1792.

Afterwards, Murdoch having made several improvements in his apparatus, between the years 1798 and 1802,* lighted up with gas the engineering works of Messrs. Boulton and Watt at Soho, near Birmingham, in the last named year. This afforded an opportunity for making a public display of the new system of lighting on the occasion of the Peace rejoicings of that time. About this period Mr. Clegg, a gentleman to whose energy and scientific skill, gas lighting in its earliest stages is much indebted, was working successfully in the same direction. In the year 1810, the Act of Parliament incorporating the London and Westminster Gas Light and Coke Company was passed, and on the 31st December, 1813, Westminster Bridge was lighted with gas. This step was soon followed by the introduction of gas in the place of oil in several of the leading thoroughfares of the metropolis.

Each ton of coal when distilled yields 10,500 cubic feet of gas, and even more. Bands of cannel coal were formerly wrought in Leverson's Colliery, Wallsend; Pelton Main and Washington, and Ramsey's colliery, Newcastle-on-Tyne. The cannel of this last-named pit yielding between 10,000 and 11,000 cubic feet of gas per ton. The bituminous coal of this district is in great request for gas-making. It would be invidious to refer to all those collieries furnishing supplies for this purpose; those selected and of which analyses are given may be regarded as some of the more important, in which the constituents appear as follows :—

Constituents.	South Peareth.	Bowden Close.	Willington.	Garesfield.
Carbon	81·41	84·92	86·81	86·9
Hydrogen	5·83	4·53	4·96	
Nitrogen	2·05	0·96	1·05	5·4
Sulphur	0·74	0·65	0·88	
Oxygen	7·90	6·66	5·22	5·2
Ash	2·07	2·28	1·08	2·5
	100·00	100·00	100·00	100·00

These coals yield coke varying from 66·70 to 72·19 per cent.

* An account of which will be found in the Philosophical Transactions for 1808.

Steam Coal and Analyses.—The best coal for steam purposes produced in the Northern coal-field lies to the north of the ninety-fathom dyke, in the Hartley district, and comprises almost all the coal north of that dyke, along the coast from Hartley, and to the crop of the coal in those districts to Warkworth. It is an interesting fact that the same bed of coal, the Hutton seam (or the Low Main of the Tyne), is not only continuous throughout almost the whole extent of the coal-field, but that it also yields the best description of three varieties of coal, suitable for purposes not at all similar to each other, viz., the best household, the best gas, and the best steam coal.

The best coals for these special purposes are obtained from the Low Main seam of the district. Recent workings have shown that the Low Main extends, as a steam coal, under the district in south-east Northumberland which produces good household coal. The annexed analyses of this and other seams of coal, will show generally the prominent constituents of the seams examined.

Constituents.	Buddles Hartley.	Newcastle Hartley.	Haswell Sunderland.	Seaton Burn.
Carbon	78·69	81·81	83·71	78·65
Hydrogen . . .	6·00	5·50	5·30	4·65
Oxygen	10·07	2·58	2·79	13·66
Nitrogen . . .	2·37	1·28	1·06	...
Sulphur	1·51	1·69	1·21	0·55
Ash . . .	1·36	7·14	5·93	2·49
	100·00	100·00	100·00	100·00

Coking and Manufacturing Coal.—The best coking coal of the district is obtained from the lower seams of the Tyne and from South Durham. Manufacturing coal, either separate or mixed with a gas coal, is associated with it, and is obtained from the lowest seam of the Auckland district. The best varieties of coke are obtained from the lower coal seams at Marley Hill, Garesfield, Wylam, Townley, &c., on the Tyne, and in Durham from the lower seams at Etherley, Brancepeth, Black Boy, &c.; the seams are said to be equivalent to the Garesfield or Brockwell seams of the Tees, and yield coke of the best quality for locomotive consumption, and for the reduction of the ores of iron in the Cleveland district. This coke is largely exported to remote

districts, its superior quality bearing a high rate for carriage. It is extensively used in the iron-making districts of the north-west coast—Lancashire, and Cumberland; also in Lincolnshire, and other districts even more remote. A second quality of coke is obtained from the Harvey or Beaumont seam, and from the washed small coal of the Hutton seam.

The Great Northern coal-field is essentially a bituminous coal deposit. It does not contain any anthracite, nor, with the exception of a thin bed in a limited locality, does it contain any cannel coal. The specific gravity of this coal varies from 1·2 to 1·5, and the quantity of carbon from 72 to 75 per cent. Further detailed particulars of this coal-field will be found in the pages of the "Coal Fields of Great Britain," by Professor Hull, F.R.S., and in the "Transactions of the Mining Engineers of Newcastle-upon-Tyne." The Low Main seam of the Tyne, the equivalent of which is the Hutton seam of the Wear, furnishes the least caking coal of the coal-field, but even the small coal when coked loses all trace of its original form, and leaves the ovens as large masses of coke. The caking coal of the coal-field, though valuable for many purposes, is entirely unfit for use in the raw state in the blast furnaces, in which its fusing property, by impeding the blast, causes the contents of the furnace to hang and slip, and thus to descend at irregular intervals. Against this disadvantage however may be placed the extreme hardness and strength of the coke it produces, which is thereby rendered capable of resisting the crushing effects of a high column of materials existing in the blast furnace. Some interesting experiments made at the Clarence Ironworks showed that a cube of coke two inches on a side, supported a weight of 25 cwt. when cold, and 20 cwt. when hot, before it was crushed.

The process of coking in the ordinary ovens may be thus explained:—When the oven is re-filled with a proper charge, the coal is fired at the surface by the radiated heat from the roof; enough air is admitted to consume the gases given off by the coal, and thus a high temperature is maintained in the roof of the oven. The coal is by this means melted; and those portions of it, which under the influence of a high temperature can of themselves form gaseous compounds, are given off, forming at the moment of their liberation small bubbles or cells; the coke now left is quite safe from waste unless a further supply of air is

allowed to have access to it. At this stage of the process the coke assumes a pentagonal form and columnar structure. When the coke is left exposed to heat for some time after it is formed, it becomes harder, and works better, from being less liable to crush in the furnace, or to decrepitate on exposure to the blast. The best variety of coke obtained from Durham coal yields the annexed results:—

Constituents.	Durham Coal.	Average Analysis.
Carbon	93·150	84·92
Hydrogen . . .	·721	4·53
Nitrogen . . .	1·276	·96
Oxygen	·905	6·66
Sulphur . . .	...	·65
Ash.	3·948	2.28
Total . .	100·000	100·00

In the Brancepeth district, the Brockwell and Busty seams of coking coal, extensively employed in the blast furnace, show the annexed results on examination:—

Constituents.	Busty Seam.		Brockwell Seam.
	Upper part.	Lower part.	
Carbon	81·22	78·46	83·40
Hydrogen . . .	4·70	4·42	4·40
Oxygen and Nitrogen .	9·45	8·82	7·18
Water	0·85	0·99	0·99
Ash	3·28	6·17	3·50
Sulphur	0·81	1·83	1·00
Total . .	100·31	100·69	100·47

The coal of the above seams yields from 60 to 65 per cent. of its weight of coke, and its purity will be understood from the appended analyses of the seams in the following collieries:—

Collieries.	Carbon.	Ash.	Sulphur.	Water.
Hamsteels	92·55	6·36	·81	·21
Consett	91·88	6·91	·84	·37
Whitworth. . . .	91·56	6·69	1·21	·54
South Brancepeth . .	93·41	5·30	·91	·36

In the following table appears the ascertained results per cent., of coke from the coal of the collieries named :—

COLLIERIES.	PER CENT.
North Percy Hartley	57·18
Newcastle Hartley	64·61
Derwentwater Hartley	54·83
Carr's Cowpen Hartley	58·59
Grey's West Hartley	59·02
Davidson's West Hartley	59·49
Haswell	62·70
Hedley's Hartley	72·31
Bowden Close	69·69
South Hetton	72·00
Willington	72·19
Leverson's Wallsend	65·10
South Peareth	72·20
Pelaw Main	69·70
Pelton Main	69·80
South Tyne	63·70
Urpeth	71·30
Washington	63·75
Old Etherley	70·00

Taking the average of numerous analytical results of the best varieties of Durham coke, 6 per cent. of ash and about ·60 of sulphur may be considered as the proportion of these constituents. Some general idea will be formed of the ash and sulphur existing in samples of the best coke from the annexed figures :—

ASH PER CENT.	SULPHUR PER CENT.
5·86	0·58
5·79	0·68
7·54	0·77
8·33	0·90

The first coke made in Durham was obtained from the Six-quarter and Blackwell coal-seams at Garesfield, belonging to the Marquis of Bute and Mr. Blackett. About a quarter of a century since the entire make of coke in all parts of the country was estimated at 2,500,000 tons a year; now, in South Durham alone, the production exceeds 4,000,000 tons. Amongst the largest producers are Messrs. Pease and Partners, the Messrs. Bell Brothers, Messrs. Strakers and Love, Messrs. Bolckow and Vaughan, and the Consett Iron Company; the first-named firm raise from their pits nearly one and a half million tons, and the Messrs. Bell Brothers one million tons

of coal annually, the greater part of which is converted into coke. The best coking coal in Durham will yield about 65 per cent. of coke: some varieties exceed this; and the inferior from 53 to 56 per cent. The local ironworks consume a large tonnage, but a great deal is sent into other iron-making districts, as well as to Sheffield, where the hard-burnt (the costliest in making, being of good size and long in shape) is extensively used in putting round the melting pots in the steel furnace.

The coking coal-field of South Durham lies principally to the west of the North-Eastern Railway going from Bradbury Station to Gateshead—the northern limit—an area of more than 250 square miles. During the past few years efforts have been made to save the gases given off in the ovens, but the success so far has not been equal to what could be desired. At several places, however, the waste heat of the coke ovens has been utilized. To have good coke it is necessary that the gases should have a free outlet, and the ovens kept burning in the ordinary way. To secure this object ovens were erected at the Brownley Colliery, and the results attained have been most favourable. The ovens were built in double rows, back to back, but with larger flues than usual between them. To each stack—about 116 feet in height—were connected about 100 ovens, an equal number on each side, there being four flues and boilers, so arranged that the heat was carried past, when cleaning or repairs were being carried on, the connecting flues being built compact and tight, so that there was great freedom from smoke, owing, no doubt, to the air-tight and perfect character of the flues, the small proportion of air present not cooling the gases to a point below, by which the hydrocarbons escaped imperfectly burnt. This was shown to be the case by admitting the air, when flame was at once seen. By this arrangement no coal whatever was used for the boilers, and the produce of the pits was drawn from a depth of 600 yards, and the water pumped; for which purpose, before the new system was adopted, 600 tons per fortnight were wasted. The amount of heat available for evaporative purposes was found to be very large.

Mr. Steavenson, of Durham, in recently noticing the ovens alluded to, gives the result of 50 of them coking at the rate of 230 tons of coal in 84 hours, which yielded 50 per cent. of coke, composed of 132·7 tons of carbon to 5·3 tons of ash, and found

that the composition and weight of the material lost in coking was:—Carbon, 62·6 tons; Hydrogen, 10·3 tons; Nitrogen, 2·3 tons; Sulphur, 1·4 tons, and Oxygen, 15·3 tons.

At several places the coal is crushed into powder before going into the oven, and this has been found beneficial, producing a larger per-centage of coke with less refuse. In some instances the coal is both crushed and washed, the washing being done in troughs. The total number of ovens in operation in Durham will be close upon 14,000, in which are invested considerably above one million sterling. The time necessary for the burning process varies considerably. An oven charged lightly for 24 hours' carbonisation—charging, burning, and drawing inclusive—will occupy in combustion 18 or 19 hours; if charged for a 48 hours' operation, with a heavier load, combustion will occupy from 30 to 32 hours. But these short hours are for a material for a specific purpose. Coke made for shipment or for smelting, and having regard to appearance and quality, will take from 72 to 96 hours in combustion, and even as much as 120 hours; in the latter time the coke is much harder, more compact and silvery-looking. Some of the Durham coal when crushed yields as much as 60 per cent. of coke, and in the ovens, the coke that was burnt the fewer hours for blast furnace purposes, was inferior to that burnt for a longer period, owing to its not being so easily oxidised into carbonic acid. Excepting the ovens and the general arrangements above referred to at Brownley Colliery, the general type of oven in use in Durham is the old bee-hive pattern. At the Consett Ironworks 150 such are in operation, being 11 feet and 11½ feet in diameter. The annual value of Durham coke exceeds two millions sterling, and it requires about 2,000 drawers to aid the operation.

Production of the Coal-field.—There is much obscurity regarding the early returns of production of this coal-field. As early as the year 1602 the vend of coal from Newcastle amounted to 190,000 tons, increasing to 239,261 tons in the year 1609, of which quantity 214,305 tons were sent coastwise, and 24,956 tons exported to foreign countries. Twenty years later the vend of Newcastle reached 289,922 tons, of which 253,380 tons were shipped coastwise, and 36,542 tons exported.

In subsequent years the figures following will show clearly the vends of the northern ports, the output of the collieries of the

Great Northern coal-field, and the total output of the collieries of Great Britain in each of the same years:—*

Years.	Vend of Northern Ports.	Production of Great Britain.
	Tons.	Tons.
1660	·537,000	2,148,000
1700	653,000	2,612,000
1750	1,193,457	4,773,828
1770	1,551,350	6,205,400
1780	1,606,244	6,424,976

The extension of the canal system between the years 1755 and 1800, led to a great expansion of the coal trade, inasmuch as the means of internal communication in the country afforded increased facilities for distribution, and gave an impetus to the use of coal in the general manufactures of the country. Between the years 1800 and 1827 no less than forty-four canals, or improvements of rivers, were projected. These receiving the sanction of the Legislature, were in due course constructed; eventually the result of this new means of communication was seen in the distribution of the coal to remote parts of the kingdom.

Again, the introduction of gas for illuminating purposes, the application of steam in our manufacturing industries and our mercantile and naval marine, the increased demand for iron due to the development of our railway system, all contributing to increased consumption, led to renewed activity and the increased prosperity, apparent in the returns of later years.

In the year 1816 the production of the Durham and Northumberland coal-field amounted to 4,826,683 tons, the output of the collieries of Great Britain the same year being 15,634,729 tons, leaving 10,808,046 tons as the produce of the other coal-fields of the kingdom. In subsequent years the returns show greatly increased production; details, however, are not readily ascertained. In 1855 more reliable returns appear in the "Mineral Statistics" of the United Kingdom. Previously the most uncertain estimates of the coal raised were prevalent; the quantities of coal carried coastwise and exported were annually published in the returns made by order of the House of Commons, but very little informa-

* "Industrial Resources of the Tyne, Wear, and Tees," read before the British Association at Newcastle in 1863.

tion was to be obtained respecting the inland traffic and distribution of coal, excepting such as was brought into the metropolitan district.

For years the Great Northern coal-field has contributed one-fourth of all the coal raised from the collieries in the United Kingdom. In the year 1879 the 363 collieries in operation produced 29,552,079 tons; the total produce of the 3,877 collieries in the United Kingdom in the same year being 134,008,288 tons.

Returning to the year 1855, when official statistics for the first time appear, the Great Northern coal-field produced 15,431,400 tons, the output of 273 collieries, thus distributed :—

NUMBER OF COLLIERIES.

Tyne, Blyth and Coquet	100
Wear and Seaham	34
Tees, Hartlepool and Stockton	64
Landsale Collieries	75
Total	273

The principal seams worked in the district may be referred to as the High Main, Five-quarter Main, Low Five-quarter, Brockwell, and Stone-coal seams. Of the coal raised in the year 1855, the following schedule shows its distribution :—

DISTRIBUTION.	TONS.
Sent to London by sea	3,016,868
Sent to London by rail	221,689
Sent coastwise to other parts	2,404,471
Railway sale	2,924,000
Sent to foreign countries	3,014,372
Used in iron works	1,200,000
Colliery consumption	1,150,000
Local consumption	1,500,000
Total	15,431,400

Following the development of this great coal-field, successive years show the returns of production as under, to which is added the produce of the collieries of Great Britain in each of same years :—

Year.	Northern Coal-field.	Great Britain.
	Tons.	Tons.
1856	15,492,969	66,645,450
1857	15,826,525	65,394,707
1858	15,853,484	65,008,649
1859	16,001,125	71,979,765
1860	18,244,708	80,042,698

The meeting of the British Association in Newcastle-upon-Tyne in 1863 gave rise to some interesting and exhaustive notices of the coal, coke, and mining industries of the North of England, including the varied trades and manufactures of the Tyne, Wear, and Tees. From these reports, prepared by Messrs. Nicholas Wood, John Taylor, John Marley, and J. W. Pease, the produce of the Northumberland and Durham coal-field in the year 1861 amounted to 21,777,570 tons. Writing at this period, now nearly twenty years since, these gentlemen conclude their observations on the duration of the coal-field as follows:—"It has been intimated that it would be very desirable that some observations should be made on the duration of the Northern coal-field. No doubt the quantity of coal yet to work in that coal-field is a subject of national importance, but from the observations already made it will have appeared that such a calculation is attended with more than ordinary difficulty. The coal-field may be said to be that of an oval basin, elongated north and south. On the western side of the basin the outcrops of the seams are pretty well defined, but more than one-half of the basin appears to be covered by the sea." At Monkwearmouth Colliery, near Sunderland, the coal is being wrought under the sea, and at Marsden, South Shields, the Whitburn Coal Company are sinking a pit, under the direction of Mr. Daglish, the eminent mining engineer, to win the coal entirely under the ocean. On examining the section from Radcliffe Colliery, at the northern extremity, the Castle Eden Colliery, near the southern extremity, the beds of coal lie at a very considerable depth below the water level of the sea, and that line of section passes through the deepest explored part of the coal-field. The lowest known point of deepest depression being the Hutton seam of coal (below which there are several workable beds of coal), which is at Monkwearmouth Colliery, 300 fathoms below the level of the sea.

Before passing on to the yield of the coal-field in later years, it will be interesting to see the several heads under which the production of the year 1861, previously referred to, was distributed, amounting to 21,777,570 tons, showing an increase over the output of the year 1860 of 3,532,862 tons, equivalent to nearly 20 per cent. The production of the collieries of Great Britain in the same year being 84,042,698 tons, of which quantity it is said nearly 4,000,000 were wasted on fire heaps.

DISTRIBUTION.	TONS.
House coal	4,493,450
Gas coal	1,717,000
Steam coal, small and manufacturing coal	4,317,120
Distributed by the North Eastern Railway	2,180,000
Distributed by Carlisle Railway	120,000
Coke consumed in iron trade	5,000,000
Alkali and other manufactures	1,250,000
Colliery and home consumption	2,200,000
Duff and waste	500,000
Total	21,777,570

As previously stated, the total output of the collieries of the Great Northern coal-field yield fully 25 per cent. of the total produce of the United Kingdom, and this proportion continues to be maintained, as appears in the returns of subsequent years, in which the total yield of the United Kingdom appears side by side with the returns of Durham and Northumberland:—

Year.	Durham and Northumberland.	United Kingdom.
	Tons.	Tons.
1862	19,360,356	81,638,338
1863	22,154,146	86,292,215
1864	23,284,367	92,787,873
1865	25,032,694	98,150,587
1866	25,194,550	101,630,544
1867	24,867,444	104,500,480
1868	24,394,167	103,141,157
1869	25,765,430	107,427,557
1870	27,613,539	110,431,192
1871	29,190,916	117,352,028
1872	30,405,000*	123,497,316
1873	29,640,385	127,016,747
1874	30,543,800	125,007,916
1875	32,097,323	131,867,105
1876	31,991,023	133,344,766
1877	31,210,400	134,610,763
1878	30,133,884	132,607,866
1879	29,552,079	134,008,228
1880†	34,913,508	146,969,409

The coal raised in the Durham and Northumberland coal-field

* Including the output of the collieries of the Cumberland coal-field.
† Return H.M. Inspectors of Mines, 1880.

was distributed and used in the following manner in each of the years 1878, 1879 and 1880 :—

Distribution and Use.	1878.	1879.	1880.
	Tons.	Tons.	Tons.
Coal exported . . .	5,838,529	6,702,785	7,066,299
*Coke do.	322,800	407,064	394,550
Coal sent coastwise . .	5,824,578	6,266,739	6,341,976
*Coke do.	8,450	8,990	11,711
Coal by rail for local consumption and land sale .	4,997,264	4,847,681	5,935,937
Coal for railway use . .	576,297	552,254	610,364
Coal by rail to other districts .	435,810	428,544	398,257
*Coke by rail for local consumption and land sale .	3,328,956	3,282,310	4,277,200
Coke by rail south of Altofts to Carlisle . .	2,073,050	2,076,757	3,955,100
*Coke for railway use . .	12,650	13,295	10,788
Coal used at iron works, mills and forges, &c. . .	2,450,500	2,250,000	2,770,000†
Colliery consumption . .	1,515,000	1,215,000	1,250,000†
Local manufactures, domestic use, &c. . . .	2,750,000	1,500,660	1,891,326†
Total . . .	30,133,884	29,552,079	34,913,508

Distribution of Coal.—All the early accounts bearing on this subject show that for a long period,—extending to a remote date,—coal was distributed through the country by means of pack-horses, mules, and asses; the coals were placed in bags and laid on the backs of these animals, and within the recollection of the present generation vast numbers of these animals were thus employed along roads and in districts impassable to carts. When roads were improved and carts could be used, the usual load for a horse was one ton conveyed ten miles a-day. About the year 1632 wooden railways were introduced and the load increased to two tons in one waggon, or four tons in two waggons on a favourable gradient. In the early period of coal mining, the pits were generally sunk on or near the outcrop of the coal-seam, or in the elevated parts of the districts; at this period two waggons were employed, an extra horse being used in the more hilly parts of the road to drag up the empty waggons. The coals thus transported were

* Equivalent in coal given.
† Estimated quantities.

conveyed from the pits to the river Tyne, from whence they were conveyed in "Keels," or boats carrying twenty chaldrons, to the ships.

About the year 1794 cast-iron rails were introduced and used at the collieries in Durham and Northumberland; these about the year 1815 were succeeded by malleable-iron rails, first in the shape of tram roads and ultimately of round-topped rails. Before the introduction of steam, horses were the motive power employed, the usual load for a horse drawing a waggon on the cast-iron roads being from ten to twelve tons, on a level or slightly inclined road, and the distance traversed daily from twenty to twenty-four miles, the waggons being loaded one-half the distance and empty the other half.

The introduction of locomotive engines on tramroads occurred in the year 1811 on the Wylam Railway, and in the following year Stephenson's improved locomotive on round-topped rails was introduced. At this period the assigned performance of a locomotive was six miles per hour, conveying a load of forty tons; a few years later the performance of a locomotive on the Liverpool Railway was thirty-three tons, conveyed at the rate of five miles per hour, by Messrs. Walker and Rastrick, and by Messrs. Stephenson and Locke, forty-five tons, conveyed at the rate of twelve miles per hour.

The first public railway, the Stockton and Darlington, was opened in the year 1825 for the conveyance of coal, minerals, and passengers; the motive power first employed was horses and subsequently locomotive engines. The first engine which ran on this railway is still to be seen in front of the station at Darlington. Since that period malleable iron rails have been universally used, and in recent years steel has been extensively introduced, and heavier rails have been laid. On the Manchester and Liverpool Railway the weight of the original rails laid was 35 lbs. per yard, forty years later the rails employed were 84 lbs. to the yard.

With the introduction of steam and railways a new era sprung up, giving a marked impetus to the development of the coal, iron, and other industries of the Empire. This is well illustrated by the rapid extension of the mineral traffic in the southern parts of the county of Durham, and by the Stockton and Darlington Railway which, as previously stated, was opened in the year 1825. Twenty years later, in 1845, and the year before the Witton Park

Ironworks were opened, the total quantity of minerals carried, including coal, coke, ironstone, and limestone, amounted to 936,757 tons, increased in the following year to 943,111 tons; five years later, with the opening of the Eston Ironstone Mines in the Cleveland district, of the North Riding of Yorkshire, the mineral traffic increased one hundred-fold, giving an aggregate of: 1,859,207 tons, and in 1856 to 2,952,202 tons, accounted for in the following items, in each of the years named:—

Distribution.	1851.	1856.
	Tons.	Tons
Coals and coke exported . .	441,352	219,591
Coals and coke, Landsale, Household and Iron Works. . .	1,017,644	1,557,624
Lime and limestone . . .	279,607	875,199
Ironstone	120,604	299,788
Total . . .	1,859,207	2,952,202

The West Hartlepool and Clarence Railways, in like manner showed a rapid development of traffic in coal and coke in each of the years:—

Years.		Tons.	Tons.
1848	Land sale . .	124,167	
	Export . . .	411,130	535,297
1858	Land sale . .	434,437	
	Export . . .	741,327	1,175,764
1862	Land sale . .	591,610	
	Export . . .	960,163	1,551,773

Previous to the introduction of railways and canals our knowledge of the detailed distribution of coal and coke is often imperfect. On the whole the following may be regarded as generally reliable, showing the quantities sent coastwise and exported; thus in the year 1602 the total quantity thus distributed did not exceed 190,600 tons; some years later the following details exhibit the extent to which the coal and coke of this coal-field were disposed of:—

Year.	Coastwise.	Foreign.	Total.
	Tons.	Tons.	Tons.
1609	224,435	27,339	251,774
1621	301,785	43,755	345,540
1630	253,380	36,542	289,922

For the next century and more, the details of distribution are somewhat meagre. In the year 1660 the coal and coke distributed amounted to 537,000 tons; forty years later the quantity did not exceed 653,000 tons, receding in 1710 to 650,000 tons. Not again until the year 1750 do returns appear, when 1,193,457 tons were carried coastwise and foreign; in subsequent years accurate data are met with showing the distribution of the fossil fuel of the Great Northern coal-field.

Year.	Coastwise.	Foreign.	Total.
	Tons.	Tons.	Tons.
1791	1,814,661	264,944	2,079,605
1795	2,251,547	418,885	2,670,432
1800	2,381,986	138,089	2,520,075
1805	2,426,616	147,146	2,573,762
1810	2,783,404	50,922	2,834,326
1815	2,717,509	159,174	2,876,683
1820	3,246,885	158,340	3,403,225
1825	3,309,386	178,544	3,487,930
1835	3,973,659	494,485	4,468,144
1840	4,517,103	1,328,445	5,845,548
1845	5,523,178	1,784,988	7,308,166
1850	6,295,570	2,176,115	8,471,685
1855	5,410,565	2,822,856	8,233,421
1860	6,360,051	4,000,712	10,360,763
1865	6,041,003	4,637,759	10,678,762
1870	5,414,266	6,635,241	12,049,607
1875	5,638,074	6,519,671	12,157,745
1876	5,785,720	6,930,305	12,716,025
1877	5,890,881	6,226,720	12,117,601
1878	5,830,501	6,071,006	11,901,507
1879	6,329,366	6,514,012	12,843,378
1880	6,349,003	7,403,029	13,752,032

Reference has been already made to the Stockton and Darlington Railway, opened in the year 1825, and to the West Hartlepool and Clarence Railway. These lines, and others, have long since been absorbed into the great system known as the North Eastern Railway, which possessed at the end of 1879 a total length in main line and branches of 1,473 miles.

Since the year 1800, the figures in the above statement show that the movements of coal coastwise and to foreign countries has increased fivefold; in the year 1879 the coal was shipped from the following ports in the quantities given :—*

Ports of Shipment.	Coastwise.	Exported.	Total.
	Tons.	Tons.	Tons.
Newcastle . . .	2,650,773	3,952,308	6,603,081
North Shields . . .	135,345	500,180	635,525
South Shields . .	239,287	361,540	600,827
Sunderland . . .	2,657,505	1,098,672	3,756,177
Stockton . . .	1,186	—	1,186
Hartlepool . . .	602,216	542,302	1,144,518
Middlesborough . .	43,054	59,010	102,064
Totals .	6,329,366	6,514,012	12,843,378

From returns furnished by the North-Eastern Railway the following abstract has been prepared, showing at a glance the magnitude of the traffic, not only in coal and coke, but also of the ironstone carried :—

Year.	Coal.	Ironstone.
	Tons.	Tons.
1854	2,571,064	——
1856	1,753,045	245,998
1858	2,402,011	259,617
1860	2,575,303	260,388
1862	3,826,590	408,979
1864	5,744,501	1,700,879
1866	7,350,956	——
1868	7,357,266	2,591,711
1870	8,999,784	2,816,797
1871	10,089,217	4,467,889
1872	10,486,168	4,652,052
1873	10,792,280	4,928,458
1874	10,689,846	4,904,279
1875	11,032,299	5,305,113
1876	10,535,438	5,426,576
1877	10,439,768	5,547,822
1878	9,907,829	4,999,448
1879	9,320.511	4,190,050
1880	11,661,676	5,785,724

The coal and coke thus carried by the North Eastern Railway

* Parliamentary Returns, No. 215, Session 2, 1880.

is exclusively the produce of the Durham and Northumberland coal-field. This is distributed for local consumption, land sale, and also employed by the railway company for their own use, in and over the main line and branches, and in those districts traversed by the railway system between Berwick and Kelso in the north, Carlisle and Tebay in the west, and Leeds, Knottingley, Doncaster, and Altofts, in the south.

Other railways contribute in a lesser degree to the distribution of the coal: thus the Great Northern Railway carried the following quantities in each of the years named; side by side are the quantities carried in each of the same years by the Furness Railways of Durham coke, from the Stockton, Darlington, and other districts from the North Eastern Railway;—considerable tonnage being also conveyed by the Midland, and Manchester, Sheffield, and Lincolnshire Railways.

Year.	Great Northern Railway.	Furness Railway.
	Tons.	Tons.
1869	509,164	330,374
1870	524,695	371,559
1871	511,165	388,096
1872	409,414	426,057
1873	365,143	489,305
1874	341,501	532,435
1875	404,313	474,336
1876	388,089	474,653
1877	334,615	579,569
1878	289,586	551,878
1879	272,896	555,180
1880	210,083	676,207

Prices of Coal and Cost of Production.—In the year 1850 the coal wrought from pits varying in depth from 750 to 1,000 feet cost on an average from 4*s*. 9*d*. to 5*s*. per ton delivered at pit's mouth; the average cost per ton at the several ports of shipment varying according to distance by rail from 5*s*. 3*d*. to 9*s*. 9*d*., or an average all round of household coals of 7*s*. 3½*d*. per ton; of steam coals, 6*s*. 8*d*. per ton, the highest price being 7*s*. 3*d*., the lowest 5*s*. 9*d*.; gas coals ranging from 5*s*. 6*d*. to 7*s*. per ton, the average being 6*s*. 1¼*d*. per ton;—the best coking coals varying from 5*s*. 9*d*. to 6*s*. 9*d*. and 7*s*. per ton, or an average through and through of 6*s*. 3¼*d*. per ton; and blacksmith's coal, 6*s*. 1¾*d*. per ton.

In 1860 the coal in the Newcastle district in the Tanfield collieries cost from 3*s.* to 3*s.* 6*d.* per ton at pit's mouth, the charges for conveyance to ports of shipment a distance of 24 miles adding 2*s.* per ton to the cost. The best coals of the Hetton district, greatly screened, all charges of labour, rent, &c., and including railway charges, 1½*d.* per ton per mile, delivered on board ship, costing from 16*s.* to 18*s.* per chaldron of 53 cwts. The average price of the several varieties of Newcastle coal, delivered free on board, in 1860, being: house coals, 9*s.* per ton; steam coals, 8*s.* per ton; and gas, coking, and manufacturing coals, 5*s.* 6*d.* per ton. The fluctuations to which the Newcastle Wallsend coals have been subject since the year 1861, is well shown in the following statement of all sales in the London coal-market in each year, showing the highest, lowest, and average price per ton:—

Year.	Average.	Highest.	Lowest.
	s. *d.*	*s.* *d.*	*s.* *d.*
1861	18 4	25 9	16 6
1862	15 7	19 0	13 6
1863	15 10	18 9	12 9
1864	17 10	22 0	14 9
1865	18 0	22 9	15 3
1866	17 9	20 6	15 3
1867	18 3	25 0	16 3
1868	15 9	18 3	14 0
1869	15 9	21 9	13 3
1870	16 3	20 6	13 9
1871	17 1	23 0	15 0
1872	23 0	29 0	18 0
1873	30 9	42 3	26 0
1874	23 2	26 6	20 3
1875	20 9	22 3	19 3
1876	19 6	23 0	15 6
1877	17 8	22 9	15 3
1878	16 6	21 9	15 0
1879	16 6	23 6	13 9
1880	14 11	18 5	13 6

The average cost is further increased by the various charges incidental to the conveyance of the coal,—from the ship to the shore, and thence to the cellar of the consumer,—adding between 5*s.* and 6*s.* per ton to the above prices. Bearing on the subject of labour, miners' wages, and arbitration in the Durham coal trade, an able article in the "Colliery Guardian" puts the subject

very clearly. The writer says: "Although the Durham coal trade has not been exempt from strikes, to which the decrease in price is generally attributed, the adjustment of the rate of miners' wages has on the whole been well managed. During the last ten years arbitration has been resorted to from time to time when differences arose as to the remuneration of labour; and with the ability and sound judgment which Mr. David Dale applied to those questions on the side of the employers, and the reason and moderation which Mr. Crawford's salutary counsels generally made to prevail among the miners, one of the most prosperous, as well as one of the most distressing periods in the trade has been tided over without any of those violent dislocations or prolonged interruptions which in former years inflicted serious injuries on all parties, and sometimes threatened to ruin local industry. In Durham the ten years under review comprise the period when this experiment has been put to the severest test, and the history of the fluctuations that have taken place in miners' wages during that period forms one of the most remarkable chapters in the records of the coal-trade,"—and is thus referred to:—

"The first years of course showed an upward movement. When the great rise in prices began in 1872, there was a general consensus of opinion that the rates current in 1871 were fair and reasonable. At all events, whether by accident or by merit, they have formed the basis of nearly all the subsequent movements. Previous to that year prices had shown little or no variation, and the collieries then worked 12½ hours a day; but the Coal Mines Regulation Act that came into operation on January 1, 1873, reduced the hours to eleven. In the beginning of 1872 the prices of coal rose so rapidly that in March the miners obtained an advance of 20 per cent. in wages over the rate current in 1871. Prices still rising, another advance of 18 per cent. was granted in July of the same year; and in February of 1873 a third advance of 15 per cent. took place, so that within twelve months the wages were 58 per cent. more than in 1871. That maximum rate continued for fourteen months, namely, till April, 1874, when a reduction of 10 per cent. took place. The next reduction followed in October of the same year, and it was fixed by arbitration at 9 per cent. Successive reductions of 5, 7, and 6 per cent. respectively were made in April, 1875, February and September,

1876. A sliding scale was then adopted, with the view of regulating wages, according to the certified prices of coal as ascertained at fixed periods. The date of the sliding scale agreement was March, 1877; and it was found that the prices of the previous four months entailed a reduction of 7½ per cent. When the last-named reduction took place, wages were about equal to what they had been in 1870 before the advances began. By the sliding scale agreement the wages now reached the minimum provided for; and as it had been pre-arranged that it should continue binding for two years, the wages continued at that rate, while prices continued to fall. In many cases local arrangements were made between masters and men to work for less wages, rather than cease working altogether; but there was no general reduction during these two years. In the spring of last year, however, steps were taken to effect a general reduction as soon as the sliding scale arrangement expired. After a good deal of negotiation, the masters reduced their first demand of 20 per cent. to 15 per cent., and many of the colliers agreed to this; but others strongly objected, and this led to a general strike throughout the country, lasting from April 14 to May 20—five weeks. The matter was settled by arbitration, which resulted in a reduction of 8¾ per cent. The coal owners claimed a further reduction in August last year; and by arbitration they were awarded 1¼ per cent., so that wages were thereafter 10 per cent. less than they were in 1871."

"Another sliding scale has since been adopted, and it differs from the previous one in this respect, that the ratio of variation is fixed, but is interminable. According to the employers' information the miners were paid 4*s.* 8*d.* a day in 1870 for an average output of 4·67 tons of coal, and 4*s.* 8¼*d.* in 1878 for an average output of 4·02 tons, being a decrease of 16 per cent. in the quantity of work done for the same wages." *

Population Employed in Coal-mines.—The number of persons employed in coal-mining in these two northern counties in the year 1852 was respectively 29,600 men and boys under ground, and 7,900 above ground, giving a total of 37,500 persons. In the year 1854 the number increased to 38,801, of whom 28,265 were employed in Durham, and 10,536 in Northumberland. The

* "Colliery Guardian," vol. xl. "Ten Years' Coal Mining," Northumberland and Durham, pp. 331–2.

total number of persons employed at this period in the collieries of Great Britain being as follows :—

	No. of Persons.
England	147,070
Wales	37,314
Scotland	32,969
Total	217,353

exclusive of females, who numbered 2,642; of these 38 were employed in Durham, and 8 in Northumberland. According to the Census returns for 1861 the number of male coal miners engaged in this great coal-field and Cumberland was 53,534, increased in the year 1864 to 57,538. The returns in subsequent years give the following as the number of persons employed, with the output of coal, from which is deduced the average output per man in each year:—*

Year.	Persons Employed.	Total Coal raised.	Average per man.
	Nos.	Tons,	Tons.
1864	57,538	23,991,544	417
1865	58,978	24,591,333	417
1866	61,367	25,693,800	418
1867	63,321	26,447,500	417
1868	69,000	26,700,000	372
1869	69,800	27,296,000	391
1870	75,100	29,300,000	390
1871	79,000	30,476,000	380
1872	84,300	30,405,000	360

Comparing the results of the year 1864 with those of 1872, when the number of persons engaged was computed by the inspector, each in his own district, we have a falling off, comparing the average output per man, of 57 tons in a period of eight years. When the Coal Mines Regulation Act, 1872, came into operation, the numbers employed were ascertained with more exactness than formerly, and appear in the following table, giving the output of coal and the average per man, showing a steady increase, amounting to 25 tons per man, in a period of six years :—

* According to H.M. Inspectors of Collieries Reports.

Year.	PERSONS EMPLOYED.		Total.	Coal raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	79,358	21,184*	100,542	29,742,617	296
1874	80,169	18,965	99,134	30,567,244	308
1875	81,913	20,225	102,138	32,324,145	316
1876	80,587	20,508	101,095	32,254,094	319
1877	79,066	19,562	98,628	31,415,225	318
1878	74,827	17,678	92,505	30,132,583	325
1879	72,138	17,471	89,609	28.788,974	321
1880	76,439	18,361	94,800	34,913,508	368

Taking the year 1879, when the total number of persons employed was 89,609, the reports of Her Majesty's Inspector give the following classification of the ages of those engaged in and about the mines:—

All Ages.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
From 12 to 13 .	1,004	——	1,004
„ 10 to 13 .	——	289	289
„ 13 to 16 .	6,495	1,783	8,278
Above 16 . .	64,639	15,399†	80,038
Total .	72,138	17,471	89,609

Resources and Probable Duration of the Durham and Northumberland Coal-field.—Adopting 4,000 feet as the limit of practical depth in coal working, and making due allowance for loss of coal destroyed by faults, barriers, and waste in working, the Commissioners engaged on the Royal Coal Commission (Mr. Thomas E. Forster for the Northumberland coal-field, and Sir George Elliot, Bart., for the Durham coal-field) give the following estimates as to the available coal remaining to be wrought in this Great Northern coal-field.‡

GENERAL SUMMARY.

	Tons.
Northumberland Coal Field	3,148,096,839
Northumberland Mountain Limestone District . .	665,180,007
Durham	6,223,363,390
Total	10,036,640,236

* The total for 1873 includes those persons employed in the Cumberland coal-field.

† Including 8 females above 16 years of age.

‡ Coal Commission Report, vol. i. p. 20—26.

The estimated quantity in the Northumberland division of the coal-field includes the under-sea coal amounting to 403,200,000 tons. This quantity is estimated on the following basis. "It is supposed that from the river Tyne northward to Creswell, a distance of 20 miles, four workable seams of coal will be found, making in the aggregate 14 feet of coal over an area of 40 square miles; taking the extent to be worked seaward at two miles equal to 25,600 acres × 14 feet thick × 1,500 tons per foot per acre, and allowing 25 per cent. to be left, the above-named quantity will be available, namely, 403,200,000 tons."

In the Durham division of the coal-field amounting to 6,223,363,390 tons, it is estimated that the total amount of undersea coal available is 2,234,509,005 tons, and in all these estimates the coal seams down to a thickness of 12 inches have been taken into account.

Taking the production of the year 1870 (27,613,539 tons) as a basis of computation, 364 years would bring about the exhaustion of this coal-field. Since the year 1870 the total output of the collieries has greatly increased, amounting in the aggregate to 302,378,849 tons; there would therefore remain in the year 1880 available coal amounting to 9,734,261,387 tons. This quantity at the average production of the ten years ending 1879 (30,237,884 tons) would afford supplies for 322 years to come; while at the rate of production in the year 1880, amounting to 34,913,508 tons, the period would be reduced to 280 years.

CHAPTER II.

THE YORKSHIRE COAL-FIELD.

Description of Coal-field—Sheffield, Leeds, and Barnsley, &c., districts—Principal Coal Seams—Analyses of Coals—Barrow Silkstone Colliery near Barnsley—Production of Coal and Distribution by Railway—Price of Coal and cost of Production—Population employed in Coal and Ironstone Mining since 1873—Resources and probable Duration of Coal-field (including Yorkshire, Derbyshire and Nottinghamshire).

The Yorkshire Coal-field.—This great coal-field occupies a considerable area of the West Riding and southern parts of Yorkshire, and with its extension into the shires of Derby and Nottingham, has a known area of about 800 square miles, its length from north to south being upwards of 66 miles, extending from Bradford and Leeds on the northern boundary, through Sheffield to Derby and Nottingham on the south, its breadth varying from 5 to 20 miles. It is the most continuous of the coal-fields of Great Britain and is almost entirely exposed throughout its area, its eastern margin only being covered by the magnesian limestone or Permian rocks. Sheffield occupies the centre of the coal-field, and in a section of 4,500 feet of coal measures 15 seams of coal occur, each seam having a thickness exceeding two feet, and giving a total thickness of 46 feet of vertical coal, while of the numerous seams less than two feet thick, there exists a vertical section equal to 53 feet of coal. In this Chapter only that part of the coal-field is described which is contained within the county of York.

The rocks of the carboniferous system are usually divided in the centre and north of England into the following groups:—

Upper Carboniferous . . .	Upper coal measures. Middle coal measures. Lower coal measures. Millstone grit.
Lower Carboniferous . . .	Yoredale rocks. Carboniferous limestone.

The lowest of these subdivisions, the *Carboniferous limestone*, consists over the greater part of its exposure in Yorkshire, as in

Derbyshire, of very little else but limestone. Partings of clay or shale between the limestone beds occur; their thickness however is inconsiderable when compared with the whole subdivision. The limestones are for the most part thickly bedded, and comparatively free from earthy or sandy admixture. Towards the top of the carboniferous limestone, the limestone beds become thinner and more earthy, and the shale partings grow more numerous, and a passage takes place into the next subdivision, the *Yoredale Rocks*. This group consists largely of dark shale, and beds of limestone and sandstone. These latter are usually thinly bedded, and more or less earthy, frequently passing into calcareous shales.

The Millstone Grit consists of sandstones thick and coarse, the individual beds showing much irregularity, although there are groups of sandstone which maintain considerable persistency over large areas. The coals here found are few in number, for the most part thin and of poor quality, and with one or two exceptions singularly local.

The Lower Coal Measures next occurring contain a few seams of coal of no great thickness and of poor quality, but an improvement upon those seams met with in the Millstone Grit. The sandstones of the lower coal measures, though important rocks, are, as a rule, neither so coarse nor so thick as the massive gritstones of the group below. It is in the lower coal measures that the hard seat-stone, known as "Ganister," occurs most abundantly, although it is not altogether absent from the Millstone grit, and the middle coal measures. "Ganister" is described as a highly silicious rock, which, when ground down and mixed in some cases with powdered fire-brick, or similar materials, forms one of the best fire-resisting materials known. Ganister is found almost exclusively in the lower coal measures, and generally forms the seat of a bed of coal. Professor Green referring to this rock, says, "There is one bed known as the 'Halifax Hard' or Ganister Coal, beneath which Ganister is almost always present; and the seat stone of this seam is not only more constant in its occurrence, but is usually regarded as of better quality than the Ganister of other horizons."

The Middle Coal Measures are alike remarkable for the number and thickness of the coal seams, and the excellent quality of their coals. The sandstones of this division are finely

grained, and not so thick as the sandstones of the two groups below; they are also much less persistent, and can seldom be traced continuously for more than a few miles.

The Upper Coal Measures consist mainly of sandstones and shales of a deep red colour. They also contain thin limestones, and although coal seams are not absent they are neither so numerous nor so valuable as those of the middle coal measures.

With this brief sketch of the Carboniferous rocks, drawn from "The Geology of the Yorkshire Coal-field"* extending from Sheffield in the south, to Leeds in the north, the next point to consider will be the order of occurrence of the principal coal seams in some of the more important localities within the area.

Analyses of Ganisters and Underclays.—These, as the name implies, usually form the seat of a seam of coal, but underclays do occur without any coal seam over them. There is usually, however, if coal be absent, a seam of highly carbonaceous black shale above an underclay. Analyses of these Ganisters and underclays by Mr. J. W. Westmoreland, formerly of the Bowling Iron Works, give the following results:—

SHIPLEY FIRECLAY BENEATH HALIFAX HARD BED.

Silica	57·45
Alumina	35·28
Peroxide of iron	4·53
Titanic acid	1·21
Lime	trace
Magnesia	1·00
Potash	·58
Moisture	·10

GIELDIN'S GANISTER, FROM PLAINTREES ROAD, NEAR LAISTERDYKE STATION.

Silica	96·55
Alumina	1·59
Peroxide of iron with some titanic acid	·71
Lime	·18
Magnesia	·17
Water	·85
Potash	·53

This Ganister is of very good quality and is used for making "holes" for crucible steel, and forms the seat of the Better Bed Coal.

* By Professor A. H. Green, R. Russell and others. ("Geological Survey Memoir," p. 20.)

Another seat stone, raised at the Bowling Colliery, also the seat of the Better Bed coal, gives on analysis the annexed results :—

Silica	81·25
Alumina	8·16
Peroxide of iron with titanic acid	4·01
Lime	·57
Magnesia	·46
Potash	1·90
Water	3·90

BETTER BED FIRE-CLAY. BOWLING FIRE-BRICK.

Silica	68·12
Alumina	26·69
Peroxide of iron	2·00
Titanic acid	·87
Lime	1·15
Magnesia	·59
Potash	1·17
Water	·20

In the northern part of the Yorkshire coal-field, a comparative section of the lower coal measures discloses the following seams of coal and intervening strata in the neighbourhood of Leeds, in a line from Royds House, by North Moor House, to Heaton Hall, in a section of 570 feet from the Blocking coal to the Better Bed coal.*

Strata.	Thickness.		Total Depth.	
	Ft.	In.	Ft.	In.
Blocking Bed Coal	2	0		
Measures	117	0		
Upper Lousey Coal	2	6	121	6
Measures	67	6		
Lower Lousey Coal	0	10	189	0
Measures	10	2		
Sandstone (Oakenshaw Rock)	120	0	320	0
Measures	120	0		
Black Bed Coal	2	3	442	3
Measures	126	0		
Better Bed Coal	1	6	569	9

The Black Bed coal is soft, friable and dull in appearance; it burns to a red ash, of which it contains about 1·5 per cent. The

* "Geology of Yorkshire," p. 202.

seam furnishes a second-class house-coal, and is largely employed locally as an engine coal. As a soft coal for producing gas it yields from 4,000 to 5,000 cubic feet to the ton, and a large proportion of gas tar.

South of Leeds the Middle Coal measures are illustrated in a section at Emley Moor, between the Blocking coal,* and the Joan coal, of 541 feet; distinguishing the thickness of the seams and the intervening measures, as follows:—†

Strata.	Thickness. Ft.	Thickness. In.	Total. Ft.	Total. In.
Measures				
Joan Coal	2	0		
Measures	64	6		
Flockton Thick Coal	3	6	70	0
Measures	15	5		
Emley Rock	26	7	112	0
Measures	11	0		
Flockton Thin Coal	1	3	124	3
Birstal Rock	83	8	207	11
Coal First Brown Metal / Measures	24	7	232	6
Old Hards Coal	2	0	234	6
Measures	25	9		
Coal Third Brown Metal	0	8	260	11
Measures	42	5	303	4
Green Lane Coal	1	2	304	6
Measures	71	10		
New Hards Coal	2	3	378	7
Measures	47	5		
Three-quarter Coal	2	7	423	7
Measures	83	6	512	1
Falhouse Rock	33	9		
Blocking Coal	1	5	541	6

The Flockton Thick Coal given above as 3 feet 6 inches thick, has a seam of clay 6 inches thick passing through it.

The other important coals occurring before the Warren House seam ‡ is reached are the following: the Haigh Moor, Swallow Wood, or Netherton Thin Coal; the Top Haigh Moor Coal, or Netherton Thick Coal, and the Twenty-seven Yards Coal band. These coals are absent in this district but are found at Kippax and elsewhere. The Warren House Coals occurring above, being represented in the Wakefield district by the Barnsley Bed.

* The Blocking coal in the north corresponds in position with the Silkstone in the south, and is the lowest of the Middle Coal-measure coals.

† "Geology of Yorkshire," p. 353.

‡ The equivalent of the Barnsley coal in the south, as regards horizon.

In the southern part of the Yorkshire coal-field the great seam is that of Barnsley. This bed so far exceeds in thickness and value any other of the known seams, with the exception of the Silkstone, that practically these are the only two coals that are wrought, and till they are exhausted no other seams are likely to be touched, except to a small extent for local consumption. The Barnsley bed, according to the authors of the "Yorkshire Coal-Field," * derives its great value from the fact that a portion of the seam is semi-anthracitic, hard, or "Steam" coal, admirably adapted for use on locomotives, in steam-vessels, and for iron smelting, on account of its high heating power. This portion of the bed is made up of alternating layers of dull and bright coal; the former being probably of a semi-anthracitic and the latter of a more bituminous character. This mixture does away with the difficulty in lighting, which is one of the drawbacks attending the use of pure anthracite, and at the same time allows of a per-centage of carbon high enough to give great heating power. The hard coal, it is observed, occurs in the middle of the seam, the upper and lower portions being soft or bituminous, and extensively used as a house coal.

The annexed section of strata in the Barnsley district gives the respective thickness of the several beds, from the magnesian limestone to the millstone grit:—†

STRATA.	THICKNESS. Ft.	In.
Magnesian Limestone	75	0
Lower Permian Sandstone	54	0
Red Rock of Rotherham	——	
Strata	0 to 100	0
Pontefract Rock	100	0
Strata	70	0
Ackworth Rock	54	0
Strata	510	0
Shafton Coal	5	0
Strata	393	0
Muck Coal	3	10
Strata	219	0
Woodmoor Coal	3	0
Strata with Half Yard Coal	45	0
Winter Coal	4	0
Strata	——	
Beamshaw Coal	3	0
Strata with Kent Coal	1	0
Mapple Coal (inferior quality)	4	6
Strata	216	0

* Professor Green, Mr. Russell and others, p. 382.

† The Rev. Wm. Thorpe's "Diagram of Yorkshire Strata."

STRATA.—*continued.*	THICKNESS. Ft.	In.
Barnsley Coal	9	3
Strata	198	0
Swallow Wood Coal	3	0
Strata	234	0
Joan Coal	2	0
Strata	60	0
Flockton Top Coal	3	3
Strata	120	0
Parkgate Coal	5	0
Strata	78	0
Thorncliffe Thin Coal	2	6
Strata	123	0
Four Foot Coal (variable)	2	6
Strata	108	0
Silkstone Coal	5	0
Strata	195	0
Whin Moor or *Low Moor Coal*	2	6
Strata . . . about	150	0
Flagstone . . . about	36	0
Strata principally shales	495	0
Halifax Coal (with Pecten papyraceus in roof and a floor of Ganister)	1	9
Strata (shales and flags)	81	0
Halifax Soft Coal	1	6
Strata	150	0
Millstone Grit.		

The "Blocking Bed Coal" previously referred to, is the lowest coal seam in the Middle Coal measures: it corresponds in position with the Silkstone Coal and is taken to be its representative. "The 'Silkstone Coal,'" says Professor Green,* "is perhaps the most highly prized of the seams of the Yorkshire Coal-field. Where at its best it is bituminous, very pure, and has the highest reputation as a house coal. Very little of it is offered for sale in the district in which it is raised, the bulk being sent to the London market. The 'Smalls' are washed and converted into coke of excellent quality." A section of the Silkstone seam south of Sheffield and the adjoining part of Derbyshire, at the Renishaw Colliery, by Mr. Appleby, is as follows †:—

STRATA.	THICKNESS.				
Roof Coal	0	6	to	0	7
Dirt	0	2	,,	0	5
Hard Steam Coal } Bright Gas Coal } Top Coal	0	11	,,	1	1
Dirt	0	0½	,,	0	4
Bottom Coal	1	6	,,	2	0
Dirt	1	3	,,	1	6
Low Coal	1	9	,,	2	0

* "Yorkshire Coal-field," p. 229. † *Ibid.* p. 229.

Analyses of Yorkshire Coal.—The Barnsley "*Three Yard Seam*," worked at Hoyland Colliery, described as being "very hard, durable, and excellent for steam purposes," varies in thickness from 7 feet 6 inches to 8 feet, and is extracted at a depth of 130 yards from surface. The sample examined very much resembled silicified wood in structure, consisting of broad layers of a brownish colour, with alternate bands of a bright jet-like substance. In the use of this coal, it was observed that the best results were obtained when a moderately quick draft was employed.

"*Barnsley Coal*," raised from Earl Fitzwilliam's colliery at Elsecar, from a depth of 154 yards, usually has a thickness of 9 feet, and is extensively employed in the various ironworks in the immediate neighbourhood of the mine. It very much resembles the Three Yard seam, but is very much brighter, and contains more iron pyrites.

"*Barnsley Coal, Park Gate Colliery.*"—This colliery is situated near the village of Rawmarsh; the seam varies in thickness from 6 feet 8 inches to 8 feet, but the average is about 7 feet 6 inches, and the coal, like the two former, is largely employed in the locality in the manufacture of iron. The above examples of the Barnsley coal on examination show the annexed constituents *:—

Constituents.	Barnsley Three-yard.	Elsecar Nine-feet.	Park Gate Seven-feet.
Carbon . . .	80·05	81·93	80.07
Hydrogen . . .	4·93	4·85	4·92
Nitrogen . .	1·24	1·27	2·15
Sulphur . . .	1·06	·91	1·11
Oxygen . . .	8·99	8·58	9·95
Ash	3·73	2·46	1·80
	100·00	100·00	100·00
Specific gravity .	1·317	1·296	1·311
Coke per cent. . .	62·50	61·60	61·70

Numerous analyses are available of coals extensively worked in the Barnsley district. The following complete series of six samples of coal showing the gaseous constituents, and chemical composition, are however selected and show the important character of the seams wrought:—

* Reports: Coal suited to the Steam Navy, 1851. Appendix, Third Report, p. 55.

Constituents.	Wombwell Main.	Darfield Main.	Oaks.	Elsecar.	Masbro' Park.	Edmunds Main.
Carbon . .	80·500	81·390	82·520	81·300	82·190	82·190
Hydrogen . .	5·500	5·500	5·025	5·190	5·173	5·080
Oxygen . .	6·205	7·451	6·915	8·210	8·144	8·243
Nitrogen . .	1·862	1·496	2·120	1·890	1·730	1·728
Sulphur . .	1·833	2·100	1·144	1·210	1·537	1·447
Ash . . .	4·100	2·063	2·276	2·200	1·226	1·312
	100·000	100·000	100·000	100·000	100·000	100·000

The specific gravity and yield per cent. of coke of each of the above is as follows:—

Coals.	Specific gravity.	Coke per cent.
Wombwell Main . .	1·266	63·130
Darfield Main . . .	1·270	63·188
Oaks	1·270	65·520
Elsecar	1·290	62·000
Masbro' Park . .	1·268	63·640
Edmunds Main. . .	1·270	63·280

The chemical composition of the ash of the same series of coals appears in the annexed statement:—

Constituents.	Wombwell Main.	Darfield Main.	Oaks.	Elsecar.	Masbro' Park.	Edmunds Main.
Silica , .	18·97	21·59	31·630	37·060	33·18	32·413
Alumina, Oxide of Iron	43·04	43·86	62·340	52·390	53·63	46·900
Lime . . .	16·87	20·68	1·902	3·266	3·35	7·000
Magnesia. .	4·90	1·93	0·900	2·450	1·11	5·690
Sulphuric Acid.	16·16	11·81	2·820	4·572	8·71	7·271
	99·94	99·87	99·592	99·738	99·98	99·274

Other important seams met with in the colliery of the Barrow Hematite Company, now in course of development at the Barrow Silkstone Colliery, about four miles from Barnsley, occur in the following descending order, and thickness:—*

	Ft.	In.
Swallow Wood Coal	3	0
Joan Coal	2	0
Parkgate Coal	4	0
Flockton Coal	2	3
Thorncliffe Coal	4	4
Silkstone Coal	5	6

* "Mining Journal," Feb. 14, 1880, p. 178.

The last-named seam occurs at a depth of 481 yards from the surface, and 61 yards below the Thorncliffe seam; it is described as a rather tender coal, with about 6 inches of dirt in the middle, and a first-class coal for coking and gas making purposes, whilst the top portion of the Thorncliffe seam, in particular, is well adapted for steam and household purposes, being very hard. The Parkgate seam is said to be inferior to the Silkstone. The chemical compositions of the Silkstone coals are as follows :—

RESULTS TABULATED.

Carbon	80·46
Hydrogen	5·08
Nitrogen	1·67
Oxygen	6·80
Sulphur	1·65
Ash	3·30
Moisture	1·04
	100·00

These results show that this coal is equal to any found in the district; possessing a high illuminating power and yielding upwards of 11,000 cubic feet of gas per ton, and when coked gives 12 cwt. of coke to the ton of coal, equivalent to 60 per cent. The Silkstone coal raised at the Hoyland Colliery, and examined by Mr. Baynes, the public analyst,* showed the same constituents as the foregoing, while as regards its illuminating power, it was found that taking a number of candles (each burning 120 grains of sperm per hour), required to yield an amount of light equal to a burner consuming 5 cubic feet of gas per hour, corrected to a temperature of 60° Fahr., and a barometrical pressure of 30 inches, the—

Average of three experiments was	17·10
The number of cubic feet of gas yielded by each ton of coal	11·650
Weight of illuminating matter per ton of coals in pounds of sperm	683·02
Volatile matter per cent.	35·52
Coke per cent.	64·48
Coke yielded by one ton of Coals	12 cwts. 3qrs. 16lbs.

This coal is also extensively coked, and is in good demand in the steelworks of Sheffield, where it is largely employed.

The coals raised in the Normanton district at Whitwood

* Barnsley.

Colliery,* suited alike for gas manufacture and for general heating purposes, show the following results. The analyses were made by Mr. Wm. Carr, of the Halifax Corporation Gas Works, who describes the samples as of "Silkstone Brights Gas Coals" and "Silkstone Hards." The mineralogical character of the gas coals is thus referred to: "Colour:—bright, black, and shining. Streak:—dull, containing slight deposit of shale. Fracture:—smooth and glossy, containing thin deposit of carbonate of lime. Cross fracture:—irregular, apparently free from iron pyrites; hard, compact, and cohesive. On the fire it intumesces and slightly agglomerates. Colour of ash:—reddish grey." The analyses of the two varieties are as under:—

SILKSTONE BRIGHTS GAS COAL.

	First.	Second.
Volatile matter	38·54	33·34
Fixed combustible matter . .	58·68	62·67
Ash	2·23	3·44
Water (expelled at 212° Fahr.)	0·55	0·55
	100·00	100·00
Specific gravity	1·268	1·268
Weight of a cubic foot . .	79·15 lbs.	79·15 lbs.

The results arrived at by a practical analysis appear in the annexed details.

RESULTS TABULATED.

	First.	Second.
Purified gas per ton of coal . . (Bar. 30″, ther. 60°)	10.949 cu. feet	11·166 cu. feet
Illuminating power of gas standard burner . .	18·22 { sperm candles	18·23 { sperm candles
Value of illuminating matter per ton of coal in sperm .	684·25 lbs.	697·90 lbs.
Hydro-carbons in gas . .	4·25 %	4·00 %
Carbonic oxide	8·50 %	9·25 %
Carbonic acid	3·00 %	2·00 %
Sulphuretted hydrogen . .	1·75 %	1·00 %
Tar produced per ton of coal .	200· lbs.	106·25 lbs.
Liquor	136·25 lbs.	293·75 lbs.
Strength of ammoniacal liquor.	5° Twaddle	3° Twaddle
Coke produced per ton . .	1362·5 lbs.	1481·25 lbs.
Ash in Coke	3·84 %	4·24 %

* Messrs. Hy. Briggs & Co., Limited.

The above results are the mean of four tests in each analysis, and show the coal to be of first class quality for heating purposes.

The "Silkstone Hards Coal" is thus described and reported upon by the same analyist:—*

MINERALOGICAL CHARACTERS.

COLOUR:—Bright, black, and shining.
STREAK:—Irregular, dull black, containing thin deposit of amorphous carbon.
FRACTURE:—Smooth and glossy, containing thin deposit of carbonate of lime.
CROSS FRACTURE:—Irregular and slightly conchoidal, apparently free from iron pyrites and shale—massive, compact, and cohesive. On the fire it splutters slightly, intumesces, and agglomerates.
COLOUR OF ASH:—Light grey.
SPECIFIC GRAVITY:—1·304 (Water=1·000) weight of one cubic foot 81·40 lbs.

CHEMICAL ANALYSIS.

Volatile matter	31·67	per cent.
Fixed combustible matter	65·57	,,
Ash	1·95	,,
Water (expelled at 212° Fahr.)	·81	,,
	100·00	

PRACTICAL ANALYSIS.

Purified gas per ton of coal (Bar. 30″, Ther. 60°)	10·654 cubic ft.
Illuminating power (Standard burner)	18·64 sperm candles
Value of illuminating matter per ton of coal, in sperm,	680·88 lbs.
Coke produced per ton of Coal (13 cwt. 2 qr.)	1·512·5 lbs.
Ash in coke	3·33 per cent.

The above results are the mean of three tests and shew the coal to be of excellent quality for heating purposes (the per centage of ash being very low, and the quantity of fixed combustible matter very high) and of fair quality for gas purposes.

Production of Coal in the Yorkshire Coal-field.—It appears incidentally from an inquiry made of the quantity of coals conveyed by canals and railways in different parts of the kingdom in 1816, that the quantity carried in and from Yorkshire amounted to 2,563,626 tons; from Derbyshire, 942,218 tons; and from Nottinghamshire, 494,665 tons, or an aggregate of 4,000,509 tons from the coal-field extending through the above-named counties. But little information showing the development of the coal resources of Yorkshire is obtainable until 1854; the shipments, however, from the several ports of Yorkshire, show a great increase, and prove the rapid extension of colliery operations

* Mr. W. Carr, of Halifax.

Thus, between the years 1819 and 1830 the total shipments of coal, from the Yorkshire coal-field, did not exceed 243,812 tons, increased to 1,042,843 tons between 1835 and 1840, and to 2,273,049 tons between 1841 and 1850. In the year 1854 the total output of the West Riding coal-field was 7,260,500 tons; the produce of the respective districts being as under:—

DISTRICTS.	TONS.
Leeds	2,040,000
Bradford	1,000,000
Wakefield	700,000
Huddersfield	300,500
Barnsley	1,250,000
Halifax	350,000
Rotherham	520,000
Sheffield	650,000
Dewsbury	450,000
Total	7,260,500

In subsequent years the number of collieries, and output of coals was as follows:—

Year.	Number of Collieries.	Coal raised.	Year.	Number of Collieries.	Coal raised.
		Tons.			Tons.
1855	333	7,747,470	1868	441	9,740,510
1856	399	9,083,625	1869	413	10,829,827
1857	374	8,875,440	1870	416	10,606,604
1858	383	8,302,150	1871	423	12,801,260
1859	383	8,247,100	1872	441	14,576,000
1860	387	9,284,000	1873	491	15,311,778
1861	397	9,374,000	1874	521	14,812,515
1862	418	9,255,500	1875	523	15,425,278
1863	415	9,402,500	1876	562	15,055,275
1864	420	8,809,600	1877	539	15,952,400
1865	434	9,355,100	1878	526	15,581,970
1866	447	9,714,700	1879	525	16,024,249
1867	454	9,843,575	1880	490	17,468,536*

Previous to the year 1871 the quantities of coal raised in the several districts of Yorkshire were separately ascertained, showing the industrial progress of each district. As these are now no longer published the returns for 1860 and 1870 will serve to show the progress between these two years.

* Report, H. M. Inspector of Mines.

Districts.	1860.		1870.	
	Collieries.	Coal raised.	Collieries.	Coal raised.
	Nos.	Tons.	Nos.	Tons.
Leeds	81	2,459,500	96	2,414,750
Normanton . . .	2		5	902,450
Bradford . . .	54	1,250,500	48	670,500
Huddersfield . . .	51	355,000	26	135,286
Barnsley . . .	42	2,430,000	44	2,250,750
Halifax	30	375,000	29	89,750
Wakefield . . .	36	820,000	47	1,125,700
Rotherham . . .	20	493,000	24	1,140,000
Sheffield . . .	29	651,000	35	975,750
Dewsbury . . .	26	450,000	31	514,877
Penistone . . .	5		6	20,660
Pontefract . . .	4		6	296,440
Bingley . . .	4		5	32,500
Saddleworth and Settle	3		2	14,036
Holmfirth . . .	...		12	23,145
Total .	387	9,284,000	416	10,606,604

The increase in the production of 1870 as compared with 1860, amounts to 1,322,604 tons, which, divided over the ten years, exhibits an increase of 132,000 tons per annum, a quantity unimportant compared with the returns of recent years. When, however, between the years 1871 and 1872 a great demand for coal arose throughout the country, the coal owners of Yorkshire at once met the industrial requirements by an increased production amounting to 1,774,740 tons over the output of 1871; and again in 1873 an increase of 735,778 tons over the preceding year, the demand being satisfied a falling off appears in 1874, amounting to 499,263 tons, since which year a steady increase is exhibited amounting in 1879 to 1,211,734 tons over the output of 1874, equivalent to an increase of nearly nine per cent. The details of production of the Yorkshire collieries are as follows for the year 1874.

DISTRICTS.	TONS.
Barnsley	3,145,150
Bradford	695,450
Dewsbury	455,520
Halifax, Huddersfield, &c.	186,150
Leeds and Normanton	4,250,000
Rotherham	2,525,500
Sheffield and Wakefield	2,595,520
Smaller districts	959,225
Total	14,812,515

Railway Distribution.—The total quantities of coal carried from the Yorkshire coal-field over the Midland Railway system in the year 1854 was 212,009 tons, increased to 363,288 tons in the year 1856. During the next few years the total quantities carried were as under:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1857	344,580	1863	563,665
1858	271,808	1864	687,124
1859	390,876	1865	438,444
1860	483,693	1866	968,600
1861	495,211	1867	1,028,353
1862	536,318	1868	1,136,539

The great influence exercised by the Midland Railway in the movement and distribution of coal, appears in the gross total carried from all districts, amounting to 2,525,751 tons in the year 1857, increased to 5,822,494 tons in 1868.

Since and during 1869 the quantities carried by this system over their own lines and that passed over to other companies for conveyance will be found in the annexed statement:—

Year.	MIDLAND RAILWAY.		Total carried.
	Own lines.	Passed to other lines.	
	Tons.	Tons.	Tons.
1869	1,246,022	140,553	1,386,575
1870	1,382,808	177,693	1,560,501
1871	1,503,650	177,243	1,680,893
1872	1,637,746	122,856	1,760,602
1873	1,872,312	108,611	1,980,923
1874	1,497,738	102,117	1,599,855
1875	1,605,600	215,572	1,821,172
1876	1,540,432	204,409	1,744,841
1877	1,732,009	217,798	1,949,807
1878	2,086,952	349,311	2,436,263
1879	2,199,892	321,328	2,521,220
1880	2,408,650	298,961	2,707,611

The North-Eastern Railway carried from Yorkshire collieries for consumption at places on their system, and to Hull and Selby for shipment, the following quantities:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1854	338,777	1868	606,689
1855	278,288	1869	675,378
1856	287,144	1870	866,422
1857	357,656	1871	1,064,407
1858	341,375	1872	1,134,542
1859	334,835	1873	1,067,651
1860	412,097	1874	1,105,021
1861	403,825	1875	1,281,248
1862	391,097	1876	1,240,645
1863	361,859	1877	1,318,887
1864	456,320	1878	1,344,318
1865	469,080	1879	1,455,895
1866	527,887	1880	1,583,942
1867	581,708		

A small proportion of the above coal is derived from Lancashire, but it is not possible to distinguish the quantities, while of the coal thus carried, from 60 to 70 per cent. is used for manufacturing, and household purposes.

The Manchester, Sheffield, and Lincolnshire Railway Company are also great carriers of Yorkshire coal. The extent of the traffic will be understood from the statement below, showing the respective quantities carried from the West Riding and from South Yorkshire, with the total weight since the year 1867 :—

Year.	West Riding.	South Yorkshire.	Total Weight.
	Tons.	Tons.	Tons.
1867	686,739	1,531,142	2,217,881
1868	665,890	1,498,356	2,164,246
1869	752,291	1,549,216	2,301,057
1870	948,600	1,679,443	2,628,043
1871	1,069,967	2,090,600	3,160,567
1872	1,127,956	2,441,683	3,569,639
1873	1,208,859	2,475,088	3,683,947
1874	1,233,044	2,421,638	3,654,682
1875	1,258,498	2,788,466	4,046,964
1876	1,111,089	2,600,070	3,711,159
1877	1,047,861	3,052,577	4,100,438
1878	1,030,464	3,067,239	4,097,703
1879	1,059,589	3,494,690	4,554,279
1880	1,104,661	3,597,637	4,702,298

The Great Northern Railway.—The total of coal and coke carried from collieries in Yorkshire in the year 1854 by this

system was 212,327 tons, increased to 474,348 tons in 1855, and 688,743 tons in 1857. Since the year 1860, the quantities carried from the South Yorkshire and West Riding districts are as follows:—

Year.	South Yorkshire.	West Riding of Yorkshire.	Total carried.
	Tons.	Tons.	Tons.
1860	409,623	9,893	419,516
1862	534,865	52,604	587,469
1866	497,418	412,829	910,247
1867	626,219	455,888	1,082,107
1868	521,739	400,783	922,522
1869	470,140	425,578	895,718
1870	551,348	443,261	994,609
1871	801,504	490,571	1,292,075
1872	874,620	680,068	1,554,688
1873	862,139	635,097	1,497,236
1874	753,162	577,048	1,330,210
1875	848,551	691,145	1,539,696
1876	719,183	706,556	1,425,739
1877	835,883	740,073	1,575,956
1878	755,808	865,570	1,621,378
1879	989,554	971,236	1,960,790
1880	863,575	971,074	1,834,649

The Lancashire and Yorkshire Railway in the year 1869 carried from the Yorkshire coal-field 1,023,261 tons, increased in the year 1880 to 1,751,510 tons; the respective quantities for each of the intervening years:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1866	805,429	1876	1,843,924
1869	1,023,261	1877	1,750,308
1872	1,359,835	1878	1,765,380
1873	1,870,452	1879	1,806,752
1874	1,756,586	1880	1,751,510
1875	1,851,639		

The London and North Western Railway, in the year 1859, carried 119,985 tons of coal from Yorkshire, and in 1865, 167,780 tons; since 1867 the total quantities carried have been as under, that passed over to other lines for conveyance being distinguished from the quantities conveyed to main line stations:—

Year.	Conveyed over Main Line.	Passed over to other lines.	Total carried.
	Tons.	Tons.	Tons.
1867	151.270	32,104	183.374
1868	166,911	29,821	196,732
1869	175,416	57,080	232,496
1870	160,848	42,357	203,205
1871	166,623	41,339	207,962
1872	219,991	5,116	225,107
1873	182,211	31,861	224,072
1874	179,231	52,797	232,028
1875	217,911	60,795	278,706
1876	207,543	60,096	267,639
1877	193,240	76,547	269,787
1878	173,874	76,891	250,765
1879	177,355	74,100	251,455
1880	157,643	79,005	236,648

Coals Shipped Coastwise and Exported to Foreign Countries.—Previous to the year 1850 there was an export duty on all coal exported in foreign ships; coals to foreign countries and our colonial possessions in British ships being free of duty. In the year 1835 the quantity of coal sent coastwise from the Yorkshire ports of Hull, Goole, and Grimsby was 129,197 tons; that sent to foreign countries being 11,977 tons, or a total movement of 141,174 tons compared with 1,480,465 tons in the year 1880, of which 146,670 tons was shipped coastwise, and 1,333,795 tons to foreign countries. The shipments were as follows in each of the years named:—

Year.	SHIPMENTS.		Total.
	Coastwise.	Foreign.	
	Tons.	Tons.	Tons.
1835	129,197	11,977	141,174
1840	159,345	32,892	192,237
1845	195,742	49,355	245,097
1850	165,889	50,862	216,751
1855	117,698	71,461	189,159
1860	133,425	249,633	382,058
1865	172,726	381,070	553,796
1870	186,501	505,139	691,640
1875	194,751	945,594	1,140,345
1876	172,360	1,023,157	1,195,517
1877	156,577	1,021,551	1,178,128
1878	128,100	1,046,556	1,174,656
1879	169,334	972,769	1,142,103
1880	146,670	1,333,795	1,480,465

Throughout the foregoing returns showing the distribution of coal, the produce of Yorkshire, a great increase appears, though not in the same proportion as in other coal-fields; the following, showing the respective quantities carried by railway, &c., in each of the years 1870 and 1879, will indicate the increase in the periods referred to:—

Distribution. By Rail and Sea.	1879. Quantities.	1870. Quantities.	Total Increase.
	Tons.	Tons.	Tons.
Midland	2,521,220	1,560,501	960,719
North-Eastern	1,455,895	866,422	589,473
Manchester, Sheffield and Lincolnshire . . .	4,554,279	2,628,043	1,926,236
Great Northern	1,960,790	994,609	966,181
London and North Western .	251,455	203,205	48,250
Lancashire and Yorkshire . .	1,806,752	1,023,261	783,491
Coastwise	169,234	186,501	450,363
Exported	972,769	505,139	

The aggregate of Yorkshire coal carried by the above-named railways in 1879 was 13,692,394 tons, against 7,967,681 tons in the year 1870, showing an increase in the movement of coal of 5,724,713 tons, equivalent to 70 per cent., and this is exclusive of the increase of coal carried by canals, the early returns of which are not available for comparison with those of recent years.

Price of Coal and Cost of Production.—Twenty years ago, in the Barnsley district, the cost of getting coal varied from 4*s.* to 5*s.* per ton. The selling price at the pit's bank varying according to the character of the coal:—"The Barnsley Bed" at this period selling from 4*s.* 6*d.* to 7*s.* per ton; the Barnsley Softs, or House Coals, from 4*s.* 6*d.* to 6*s.*; "Hards," or Steam Coal, from 6*s.* to 7*s.*; "the Silkstone Bed" commanding a higher price, from 6*s.* to 8*s.* per ton. Ten years previously, in 1851, the average selling price of coals per ton at the pit's mouth in Yorkshire varied from 7*s.* per ton for ordinary coals to 8*s.* 4*d.* for best household coals. In Sheffield the prices ruling at the wharves were as follows per ton:—

		s.	*d.*
Picked coal for steel making		10	0
House coal	7*s.* 6*d.* to	8	4
Engine coal.		5	0
Hard coke for steel smelting		15	6

an additional charge of from 8*d.* to 1*s.* per ton being added for cartage.

In 1870 prices exhibited but little variation compared with 1860. The Barnsley "Hards" were selling for 7*s.*; House Coal, 6*s.*; Engine Coal, 4*s.*, and Slack, 1*s.* 6*d.* per ton;—the best coals of Bradford, at Bowling, being quoted at 9*s.* per ton, and Seconds at 7*s.* 6*d.* and 5*s.* In the Leeds district the best coals varied from 8*s.* to 9*s.* 6*d.* per ton; the Seconds, from 5*s.* to 7*s.* 6*d.*, and Slack, from 2*s.* to 2*s.* 9*d.* per ton. During the years 1871 to 1873 prices rose, due in a measure to the demand but more especially to the operation of the Coal Mines Regulation Act, which took effect about that time. Since that date, however, prices have fluctuated, and in 1878, 1879, and 1880 the following may be generally regarded as average, highest, and lowest prices of coal and slack at the pit's mouth in the Yorkshire collieries:—

Year.	Coal and Slack.	Average.	Highest.	Lowest.
		s. *d.*	*s.* *d.*	*s.* *d.*
1878				
	Coal (per ton) . .	8 0	10 6	6 0
	Slack ,, . .	4 0	5 4	2 6
1879				
	Coal ,, . .	7 9	14 0	6 0
	Slack ,, . .	4 4	5 10	2 0
1880				
	Coal ,, . .	8 0	11 0	6 0
	Slack ,, . .	4 6	5 0	2 0

In respect to wages, it has been generally observed that colliers in Yorkshire have been better paid than in other coal-fields. It is not, however, so easy to give an exact account of the variations in the cost of production, as in Yorkshire payment is usually made by the ton of coal raised, instead of by the day, and as the seams are of varying qualities and thickness the rate varies in different districts and in different seams. It is a fact, however, that the rate rose as quickly and as much in Yorkshire as in any other coal-field during the prosperous years of 1871—73. In the last-named year there were instances in which the colliers were getting exactly 150 per cent. more for their labour than in 1868; but these were extreme cases. In 1871, which is taken generally as a fair basis of comparison, certain collieries paid 3*s.* 7*d.* per ton for the labour of raising the coal; that rate rose in 1872 to 5*s.* 7*d.*, and in 1873 it reached 7*s.* 1*d.* The latter extreme rate only lasted a short time. The average maximum

would be more accurately stated at 6*s.* 5*d.*, an increase of over 80 per cent. When wages were at that high pitch, there were undoubted instances in which some of the most industrious and efficient colliers made as much as five pounds per week. In South Yorkshire, about the middle of 1879, the wages of miners averaged 5*s.* 3*d.* a day, or 27*s.* a week for hewers, while in Durham at the same time the average rate was 4*s.* 2*d.* a day.*

Population Employed in Coal and Iron-stone Mining.— The total number of persons of all ages engaged in the Yorkshire coal-field in the year 1854 was 22,194; of these 21,030 were employed in coal mining, and 1,164 in iron-stone mining. The census for 1861 gives the number, including all employed in and about the mines, as 31,938, the quantity of coal raised the same year amounting to 9,374,600 tons, giving an average yield of 293 tons per man. It was not, however, until the year 1873 that the exact number of persons employed was ascertained under the clauses of the "Coal Mines Regulation Act, 1872." It will, however, serve for comparison to note the inspector's returns previous to 1873, which give the aggregate number of persons employed, together with the quantity of coal raised in each year, and the average yield per individual:—

Year.	Persons employed.	Coal raised.	Average per Man.
	Nos.	Tons.	Tons.
1861	31,938	9,374,600	293
1864	34,500	9,300,000	270
1865	35,000	9,300,000	266
1866	35,500	9,450,000	266
1867	37,000	9,850,000	266
1868	37,000	9,705,000	262
1869	36,000	10,893,000	302
1870	36,500	11,545,000	316
1871	38,600	12,801,260	331
1872	51,056	14,576,000	285

Comparing the average produce per man in 1872 with 1871, a falling off appears of 46 tons, due to the greater number of persons employed in the year 1872; this is explained by Mr. Frank N. Wardell, the inspector of the district, in his evidence given before the "Select Committee on Coal, 1873," † in

* "Colliery Guardian," 1880, p. 382.

† Report Select Committee on Coal, 1873, p. 32, Question 687.

reply to a question: "But do you know whether this increase has been chiefly or entirely of men working under ground, or of men working above ground?" "I believe that this return of persons employed which has been given to me this year is a very much more accurate one than has ever been given before, and for this reason, that the return which is now required by this new Act of Parliament embraces every single person, man and boy, employed about the mine, from the face in the pit to the staiths outside; and I believe there are thousands that I have had returned to me this year who were never returned in any shape or form before."

In the year 1873, for the first time, it was ascertained that the total number of persons employed in the collieries of Yorkshire was 57,523; of these 45,828 of all ages were engaged under ground, and 11,695 above ground, their ages being distinguished as follows. In the same year 491 mines were in operation, raising coal, fireclay, and ironstone.

Ages.	Under Ground.	Above Ground.
	Nos.	Nos.
From 10 to 12 . .	837	374
,, 10 to 13 . . .	...	10*
,, 12 to 13 . .	1,846	...
,, 13 to 16 . . .	6,807	712†
Above 16 . . .	36,338	10,599†
Total	45,828	11,695

The total of minerals wrought in the coal-field in 1873 amounted to 15,695,249 tons, made up of coal, 15,311,778 tons; fire-clay, 149,130 tons; and ironstone, 234,341 tons, giving an average of mineral wrought to each person employed of 273 tons. The number of persons employed under ground, and above ground, and of the minerals wrought in each year since 1873, appear in the following table, together with the average yield of mineral per person, amounting in the year 1880 to 295 tons.‡

* Including 8 females.

† Including 15 females.

‡ Reports of H.M. Inspectors of Mines.

PERSONS EMPLOYED AND MINERALS RAISED IN YORKSHIRE SINCE 1873.

Year.	PERSONS EMPLOYED.			MINERALS RAISED.			Total Minerals raised.	Average per man.
	Under Ground.	Above Ground.	Total.	Coal.	Fire Clay.	Iron Stone.		
	Nos.	Nos.	Nos.	Tons.	Tons.	Tons.	Tons.	Tons.
1873	45,828	11,695	57,523	15,311,778	149,130	234,341	15,695,249	273
1874	49,683	12,816	62,499	14,827,313	187,819	212,777	15,221,909	243
1875	49,006	13,184	62,190	15,855,990	183,961	236,782	16,276,733	262
1876	48,367	12,650	61,017	15,129,506	183,234	240,116	15,552,886	254
1877	47,808	12,786	60,594	15,805,235	188,346	249,454	*16,247,851	268
1878	47,985	11,792	59,777	15,582,283	174,865	226,793	†15,995,165	267
1879	48,327	11,760	60,087	16,241,443	155,938	199,856	‡16,628,707	276
1880	48,654	11,820	60,474	17,468,536	178,987	180,250	§17,870,342	295

* Including 4,816 tons of oil shale.
† " 31,470 " "
‡ " 11,224 " "
§ " 42,569 " "

The distribution of labour in Yorkshire shows more than ordinary uniformity throughout the depression of recent years. Since 1873, the average production per man has only once shown any notable variation. This falling off in production occurred in the year 1874, when 4,976 persons were employed in excess of the previous year, the output of coal being 484,465 tons less. The cause is thus explained. In the previous years of scarcity there was a great demand for more labour at the collieries, and it was not till 1874 that that demand was satisfied. It was met however by the influx of all sorts of unskilled labour. Artisans and labourers from other trades were attracted by the high rate of wages offered and flocked to the collieries; but they were necessarily less efficient than a corresponding number of trained hands would have been. Some eighteen months or two years' experience are considered necessary to make an efficient collier, and hence we find that in Yorkshire the anomalous state of the colliery labour that prevailed in 1874 did not continue.

The actual output per man, due to the different positions and thickness of the coal-seams in different collieries show great variations. In some of the best collieries of the district the actual output per man has been as high as 500 tons per annum, in others it has not exceeded 190 tons. In addition to the difference of the character of the coal worked, the number of days which the men worked also affects their actual output. In some districts the collieries have been known to work double the time of others.

During the year 1879 there were 24 new pits being sunk in Yorkshire; most of them being near Leeds and Sheffield, there being only one or two new sinkings near Barnsley.

Of the persons employed in the year 1879 in the Yorkshire coal-field, the following statement will show their respective ages:—

Ages.	Under ground.	Above ground.
	Nos.	Nos.
From 10 to 12 . .	250	...
,, 10 to 13 . . .	...	118
,, 12 to 13 . .	769	...
,, 13 to 16 . . .	5,503	848
Above 16 . . .	41,805	10,783
Total . . .	48,327	11,760*

* Including eleven females employed above ground.

Resources and Probable Duration of the Midland Coal-Field.—The coal-fields of South Yorkshire, Derbyshire, and Nottinghamshire comprise a part of the Midland coal-field. The late Mr. J. T. Woodhouse, a member of the Royal Coal Commission, to whom was entrusted this enquiry, has arrived at the following results. The acreage of the coal-field being divided as under:—

Name of District.	Total Acreage.	Acreage Unwrought.
	Acres.	Acres.
Outside the Permian		
Midland	6,039,615	5,856,948
Midland deep coal . . .	265,590	265,590
Proved Sub-Permian		
Midland	1,523,396	1,519,517
Midland deep coal . . .	141,555	141,555
Total acreage . . .	7,970,156	7,783,610

The quantity of coal estimated as originally existing in the coal-field, all necessary deductions being made for coal which cannot be worked by reason of its being left for boundary pillars, faults, broken ground, waste in working, &c., gave a total of 33,768,362,814 tons, the quantity remaining unwrought, 32,721,198,832 tons, and the net tonnage remaining and available for future supplies, 18,406,799,443 tons.

The details of these quantities apportioned in districts are as under :*—

Name of District.	TONNAGE.		
	Total estimated tonnage.	Tonnage remaining unwrought.	Net tonnage available for consumption.
	Tons.	Tons.	Tons.
Outside the Permian			
Midland	24,714,936,964	23,693,839,102	13,327,784,524
Midland deep coal . .	747,285,800	745,285,800	420,348,320
Proved Sub-Permian			
Midland	7,801,543,230	7,777,477,110	4,374,830,886
Midland deep coal. .	504,596,820	504,596,820	283,835,713
Total . . .	33,768,362,814	32,721,198,832	18,406,799,443

* Report Coal Commission, vol. i., p. 31.

It is only necessary to add, that the tonnage estimates are made on the assumption that each cubic foot of coal weighs 80 lbs., which equals within a fraction a yield of 1,536 tons per foot thick per statute acre, and that the depths considered in the estimates of coal yet available for consumption, are 3,000 feet, and in the case of the Midland deep coal, from 3,000 feet to a depth not exceeding 4,500 feet.

Following the consumption of coal during the ten years ending 1879, some interesting results appear regarding the production of the Midland coal-field during the decade ; the total output increasing from 17,824,241 tons in the year 1870, to 27,723,861 tons in the year 1879.

That an estimate may be arrived at of the probable exhaustion of the coal area embracing Yorkshire, Derbyshire, and Nottinghamshire, the resources of which are given above, the annexed statement, showing the annual production in each area of the coal-field during the past ten years, will afford the necessary data for the computation :—

Year.	MIDLAND COAL AREA.			
	Yorkshire.	Derbyshire.	Nottinghamshire.	Total.
	Tons.	Tons.	Tons.	Tons.
1870	10,606,604	5,102,265	2,115,372	17,824,241
1871	12,801,260	5,360,000	2,469,400	20,630,660
1872	14,576,009	*5,700,000	*2,650,000	22,926,000
1873	15,311,778	*6,250,000	*2,800,000	24,361,778
1874	14,812,515	7,150,570	3,127,750	25,090,835
1875	15,425,278	7,091,325	3,250,000	25,766,603
1876	15,055,275	7,025,350	3,415,100	25,495,725
1877	15,592,400	6,975,550	3,895,750	26,463,700
1878	15,581,970	7,190,000	4,107,350	26,879,320
1879	16,024,249	7,450,370	4,249,242	27,723,861
Total	145,787,329	65,295,430	32,079,964	243,162,723

Glancing at the total production of this great coal-field in the ten years ending 1879, amounting to 243,162,723 tons, the relative proportion of output appears as follows :—Yorkshire, 60 per cent.; Derbyshire, 27 per cent., and Nottinghamshire, 13 per cent.; while as regards the output in 1879 compared with 1870 an

* Estimated production.

increase appears equivalent to 55 per cent. Notwithstanding the resources of this coal-field it is quite clear they are being rapidly utilized. For example, at the rate of production in 1870 (17,824,241 tons), supplies would be available for 1,033 years. Deducting the production of the past ten years from the original estimate, there yet remain 18,163,636,720 tons for future supplies, to depths exceeding 4,000 feet after making the necessary deductions.

MIDLAND COAL FIELD.	TONS.
Original quantity available	18,406,799,443
Ten years' produce ending 1879	243,162,723
Total available 1880	18,163,636,720

Arguing from these data, and taking the production of 1879 as a basis (27,723,861 tons), the resources would be exhausted in 655 years hence; taking the average of the past ten years, (24,316,272 tons), 747 years would be the limit. The total exhaustion may, however, be expected at a much earlier period, seeing that the production during the past decade has increased to the extent of 55 per cent.

H. M. Inspector's returns for 1880 give the production of this great coal-field as follows:—

	TONS.
Yorkshire	17,468,536
Derbyshire	7,903,834
Nottinghamshire	4,432,393
Total	29,804,763

Showing an increase over the previous year of 2,080,902 tons, and giving 609 years hence as the period of the exhaustion of this coal area.

CHAPTER III.

CUMBERLAND AND WESTMORELAND COAL-FIELDS.

Description of Cumberland Coal-field—Strata and Coal Seams in Whitehaven and Workington Districts—Analysis of Coal—Prices, Production, and Distribution by Railway, Coastwise and Exported—Population employed in Coal Mining—Resources and Probable Duration of Coal-field—Westmoreland Coal-field—Population Employed and Coal Raised.

The Cumberland Coal-field.—The total length of this coal-field is twenty miles, and its greatest width, which occurs at Workington, nearly five miles. The coal measures in this area attain a thickness exceeding 2,000 feet, the middle division containing seven and the lower four workable seams of coal, those latter being thin and inferior.

Many of the seams in the middle measures are of considerable thickness and regularity; these seams will be recognised in the accompanying section of strata at Whitehaven.*

	THICKNESS. Feet.
Strata	432
Yard band	3
Strata	30
Coal	2½
Strata (with a coal seam)	78
Bannock Band	8 to 9
Strata	60
Main Band	6 to 11
Strata	240
Low Bottom Coal	4

Again, in the Workington district the following seams are met with:—

	THICKNESS. Ft.	In.		Ft.	In.
Fiery Band				2	0
Brassy Band				2	3
Cannel or Metal Band	4	0	to	6	0
Bannock Band				5	6
Lower Main Band	3	0	to	4	0
Main Band	9	0	,,	10	0
Yard Coal	2	0	,,	3	0
Four Foot Coal				4	0
Udale Band	3	0	to	4	0

The total thickness of workable coal in Cumberland is estimated to amount to 35 feet.

* "Coal Fields of Great Britain," 4th ed., p. 227.

Mining operations are carried out on an extensive scale in the Whitehaven district, where the colliery workings extend from two to three miles under the sea. At Workington also, the coal seams have long been wrought under the sea; and Mr. M. Dunn,* describing the dangers attending these undersea operations from inundation, gives an account of a sad calamity which occurred in this district in July, 1837, when 36 men and boys, and as many horses, together with all the extensive stock under ground, were irrecoverably destroyed from this cause, the waters having filled up the whole of the extensive workings to the level of the sea in a few short hours.

The scene of the accident was the Workington Colliery, where the pits "Lady" and "Isabella" were sunk and the coal worked to the distance of 1,500 yards under the Irish Sea, in a 10 feet seam which was 90 fathoms deep, both pits being situated close upon the sea shore. The workings were driven considerably to the rise, at the rate of one in three, which brought them within 15 fathoms of the bottom of the sea; operations appear to have been carried out in a very unguarded manner, the seams were worked up too far towards the bed of the sea which gave way, flooding the colliery and leading to the disastrous results above noticed.

Analysis of Coal.—In the following appears a chemical analysis and practical assay of an average sample of Cannel coal, from a seam about five inches thick, worked in the Dovenby Colliery, Dearham, Maryport; and made by Dr. William Wallace, Gas examiner for the City of Glasgow.

ANALYSIS.

Volatile matters	Gas, Tar, &c.	52·65	54·47
	Sulphur	·66	
	Water, at 212° Fahr.	1·16	
Coke	Fixed Carbon	26·25	45·53
	Sulphur	·92	
	Ash	18·36	
			100·00

	Cwts.	Qrs.	Lbs.
Coke (dry) per ton of coal 1010 lbs., or	9	0	2

ANALYSIS OF THE COKE (DRY).

Carbonaceous or combustible matter	57·65
Sulphur	2·02
Ash	40·33
	100·00

* "Winning and Working of Coal Mines, 1848," p. 230.

Specific gravity of the coal	1·271
Weight of a cubic foot in pounds	·79

PRACTICAL RESULTS.

Gas, per ton of Coal, at 60° Fahr., and 30 inches barometer	10,765 cubic feet.
Illuminating power, in standard sperm candles, by union jet consuming 5 cubic feet per hour at ·5 inch pressure	40·48 candles
Value of one cubic foot of gas, in grains of sperm . .	971
Equivalent of a ton of coal in pounds of sperm candles . .	1493
Durability of one cubic foot of gas, by 5 inch flame .	83 minutes
Gravity of the gas, air = 1000	660

REMARKS.

The gas from this coal is equal in quality to that made from the celebrated Boghead Cannel, and is too rich for illuminating purposes. It is, owever, very valuable for mixing with gas made from ordinary soft coal or inferior cannels.

Prices of Coal.—A few general notes will show the average prices of house coal at the pit's mouth in Cumberland. In the year 1851 the average price per ton was 4*s*. 6*d*., increased in 1856 to 6*s*., prices gradually decreasing till, in 1859, the quotations for house coal were 5*s*. 8*d*., in 1864 the average was 6*s*. 10*d*., and in 1866, 8*s*., varying in 1868 from 6*s*. to 6*s*. 6*d*. per ton. In 1870 we learn from the Coal Commission report* that the following were the average prices of coals at the collieries named (best coals):—

COLLIERIES.	*s.*	*d.*
Broughton Moor	8	4
Flimby Best Coal	5	9
Frizzington	7	6
Gillhead	6	8
Harrington	10	0
Threapthwaite	9	2

The prices of slack varying from 2*s*. 6*d*. to 3*s*. 4*d*. and 5*s*. per ton, according to quality. In the years 1878, 1879 and 1880 the average prices of coal and slack per ton were as follows:—

Year.	COAL.			SLACK.		
	Average.	Highest.	Lowest.	Average.	Highest.	Lowest.
	s. *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
1878	8 6	10 10	7 6	3 6	5 0	2 1
1879	8 0	10 0	6 6	4 0	5 11	3 0
1880	9 0	†20 0	7 6	4 3	5 1	3 6

* Vol. iii., "Statistics," Appendix, p. 212.
† Cannel coal.

Production of Coal in Cumberland.—From the report of the Royal Coal Commission many important facts are gleaned bearing on the early history of the coal trade of Cumberland; it is there stated that in the year 1582 the Earl of Lincoln, being Lord High Admiral, caused an account of the ships and mariners of Cumberland to be taken. The vessels amounted to twelve, not one of them being of 80 tons burden; mariners and fishermen, 198.* The insignificant condition of the ports of Cumberland, even so late as the middle of the last century, is shown by the facts that in the year 1752 Maryport consisted of only one farmhouse, and in that year a second house was built.

Coal was first worked at Whitehaven by Sir John Lowther, in the year 1660, and it further appears from Lyson † that steam-engine fuel was used in the year 1787, in which year Whingill and Howgill collieries produced 112,500 tons of coal. But little information is met with giving the output of the Cumberland collieries at an early period; on the other hand the Custom-house returns show the quantities of coal exported from the several ports of Cumberland between the years 1781 and 1792.‡ The great bulk of the coal exported at this period was sent to Ireland, the duty chargeable being 1*s.* 2*d.* per ton, while the coal exported to foreign countries was fixed at 5*s.* per ton.

Year.	Whitehaven.	Workington, Maryport, and Harrington.
	Tons.	Tons.
1781	119,540	118,525
1782	123,393	118,164
1783	131,442	125,526
1784	128,312	136,336
1785	156,279	151,738
1786	188,082	142,622
1787	109,181	164,828
1788	193,633	162,228
1789	162,611	160,046
1790	144,947	152,819
1791	117,401	179,645
1792	125,840	169,291

The average exports of coal from the Whitehaven Collieries about the year 1814 did not exceed 225,000 tons per annum, to

* A General View of the Agriculture of Cumberland.

† Lyson's "Magna Britannia," p. cxxi.

‡ "History and Antiquities of Cumberland," by Wm. Hutchinson. Carlisle. 1794.

which adding the coal of the inland collieries estimated at 15,000 wagon loads of two and-a-half tons each, or 33,750 tons, the total production at this period may be set down at 258,750 tons.

Forty years later it appears that the total output of the Cumberland collieries amounted to 887,000 tons, of which 580,241 tons were shipped from the ports of Cumberland, the prices per ton being quoted at 8*s.* 5*d.* shipped and forwarded by rail; and 8*s.* 4*d.* for household purposes; the quantity shipped in the previous year amounted to 555,216.

In 1854 and since, the following gives the number of collieries and the annual output of coal:—

Year.	Number of Collieries.	Coal.	Year.	Number of Collieries.	Coal.
		Tons.			Tons.
1854	23	887,000	1867	25	1,512,514
1855	23	809,546	1868	27	1,378,026
1856	28	913,981	1869	26	1,410,808
1857	28	942,018	1870	27	1,408,235
1858	28	920,137	1871	27	1,423,661
1859	28	1,041,890	1873	37	1,747,064
1860	28	1,171,052	1874	34	1,102,267
1861	28	1,255,644	1875	36	1,226,737
1862	28	1,330,287	1876	37	1,399,603
1863	32	1,327,368	1877	35	1,515,783
1864	30	1,380,795	1878	31	1,392,773
1865	30	1,431,047	1879	33	1,459,170
1866	30	1,490,481	1880	27	1,680,841

Distribution of Coal.—Commencing with the year 1867, and until the year 1871, we have the following statement showing the distribution of the coal produced in Cumberland in each of those years, the coal sent coastwise being chiefly shipped to Irish ports where it is largely employed for household purposes:—

Year.	Exported.	Coastwise.	Ironworks.	Domestic.
	Tons.	Tons.	Tons.	Tons.
1867	782,723	5,591	478,500	245,700
1868	10,664	675,632	459,730	250,000
1869	8,964	670,584	453,150	278,110
1870	7,689	670,421	450,125	280,000
1871	3,739	599,922	525,000	295,000

A few details will generally indicate the movements of coal;

for example, the London and North-Western Railway, the Furness Railways, and the Maryport and Carlisle Railway, carried of Cumberland coal the following quantities in each of the years named :—

Year.	London and North-Western Railway.	Furness Railway.	Maryport and Carlisle.
	Tons.	Tons.	Tons.
1868	389,487	48,258	...
1870	345,046	43,930	...
1871	348,668	45,614	...
1872	384,071	43,646	184,450
1873	348,404	50,982	282,787
1874	266,866	54,787	245,671
1875	268,737	48,541	222,766
1876	318,383	51,476	291,235
1877	361,276	47,303	268,978
1878	374,282	33,908	282,242
1879	354,664	54,808	305,460
1880	371,755	36,965	274,602

Following the railway distribution since the year 1872 the annexed table shows the quantity shipped from the respective ports of Cumberland, coastwise and to foreign countries, the latter being inconsiderable.

Year.	COASTWISE.			FOREIGN.
	Workington.	Whitehaven.	Maryport.	Total.
	Tons.	Tons.	Tons.	Tons.
1872	53,787	121,823	154,815	3,288
1873	35,324	89,033	240,104	490
1874	20,774	100,245	236,205	2,719
1875	28,637	128,590	234,293	2,402
1876	47,038	130,290	276,784	5,516
1877	47,318	133,281	294,957	6,128
1878	56,334	129,540	282,607	6,837
1879	53,718	217,245	292,526	3,500
1880	52,980	198,761	242,176	1,569

Since the year 1876, Carlisle (Silloth) has shipped coal coastwise. These quantities added to the above, increase the total shipments coastwise which appear as follows since 1876 :—

Year.	Carlisle.	Total Shipments.
	Tons.	Tons.
1876	45,791	499,993
1877	31,994	507,550
1878	28,518	495,999
1879	21,170	584,559
1880	20,088	514,035

Of the production of Cumberland in the years 1874, 1879, and 1880, the annexed table shows the distribution of coal.

How Distributed.	1874.	1879.	1880.
	Tons.	Tons.	Tons.
Coastwise	357,224	584,559	514,035
Exported	2,719	3,500	3,858
London and North-Western Railway	266,866	354,664	371,755
Maryport and Carlisle Railway	245,671	101,061	99,465
Furness Railway . . .	54,787	54,808	36,965
Collieries, ironworks, and local consumption . .	175,000	365,275	654,763*
Total . . .	1,102,267	1,463,867	1,680,841†

Population employed in Coal-mining.—The number of persons thus employed in the year 1854 above and below ground in Cumberland was 3,948, of whom 3,579 were engaged in coal mines and 369 in ironstone mines. Previous to the year 1874, the persons employed in coal-mining operations in Cumberland are included in the returns of Durham and Northumberland. Since that date they are separately distinguished and are as follows; side by side appear the coal raised each year, and, for comparison, the quantities raised per man:—

Year.	Under Ground.	Above Ground.	Total Persons.	Coal Raised.	Average per Man.
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	4,251	1,427	5,678	1,036,274	183
1875	4,763	1,745	6,508	1,171,341	180
1876	4,401	1,623	6,024	1,392,046	231
1877	4,381	1,440	5,821	1,447,223	248
1878	4,253	1,525	5,778	1,393,514	241
1879	4,281	1,528	5,809	1,525,039	262
1880	4,407	1,537	5,944	1,680,841	283

* Estimated quantity.

† According to Returns of H.M. Inspectors, 1880.

The respective ages of those engaged under and above ground in 1879 are thus distinguished :—

CUMBERLAND.

Male Persons.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
From 12 to 13 . . .	18	...	18
,, 10 to 13 . .	...	1	1
,, 13 to 16 . . .	292	85*	377
Above 16 . . .	3,971	1,442†	5,413
Total . . .	4,281	1,528	5,809

The average tonnage of coal raised per man during the above seven years showing an increase of 100 tons—equal to 55 per cent.

Resources of Cumberland Coal-field and Probable Duration.— The quantity of coal remaining unworked in the Cumberland coal-field, according to the Report of the Royal Coal Commission, amounts to 405,203,792 tons thus summarised :—‡

THICKNESS OF SEAMS.	YIELD OF COAL ESTIMATED.
	Tons.
From 12 in. to 18 in. thick	8,403,414
,, 18 ,, 24 ,, ...	25,579,019
,, 24 ,, 30 ,, ...	18,105,665
,, 30 ,, 36 ,, ...	52,793,908
,, 36 ,, 42 ,, ...	9,308,974
,, 42 ,, 48 ,, ...	6,770,890
,, 48 ,, 54 ,, ...	21,591,388
,, 54 ,, 66 ,, ...	32,015,571
,, 66 ,, 72 ,, ...	30,786,747
,, 72 ,, 84 ,, ...	43,989,529
,, 84 ,, 112 ,, ...	54,482,687
Total tons of coal to be worked from the Cumberland Coal Field as per returns made from the collieries	303,827,792
Under Sea Coal.—It is estimated that for a distance of eight miles, two workable seams of coal will be found under the sea, making in the aggregate 11 feet of coal over an area of 16 square miles; taking the extent to be worked seaward 2 miles = 10,240 acres × 11 feet, and allowing 40 per cent. to be left = ...	101,376,000
Total	405,203,792

* Including 7 females. † Including 329 females.

‡ Coal Commission Report, vol. I., p. 21.

This quantity, at the rate of production in the year 1870, viz., 1,408,235 tons, would afford supplies for 288 years. During the ten years ending 1879, the output of the collieries of Cumberland amounted to an aggregate of 14,080,029 tons, or an average annual output of 1,408,002 tons; leaving a total of 391,123,499 tons yet available for a period of 277 years. The output of the collieries of Cumberland in 1880 was 1,680,841 tons, showing an increase over the previous year of 155,802 tons, and reducing the period of duration to about 235 years.

Westmoreland Coal-field. Population Employed and Coal Raised.*—The coal produced in Westmoreland is inconsiderable, not exceeding 2,000 or 3,000 tons in any one year. In the year 1854 the total number of persons engaged in coal and iron mining was 109; of these 57 were engaged in coal, and 52 in iron mining. The returns of recent years, as under, show a considerable falling off. The details are as follows:—

Year.	Persons Employed.		Total.	Coal raised.	Average per man.
	Under ground.	Above ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	20	3	23	1,972	86
1874	12	1	13	1,297	99
1875	18	1	19	2,566	135
1876	13	2	15	2,020	135
1877	13	2	15	2,051	136
1878	15	2	17	1,830	108
1879	17	2	19	2,026	106
1880	13	3	16	1,950	122

In the years 1877 and 1879 the number engaged in iron-mining was but ten in each year, of whom six were engaged in underground and four in overground operations; the quantities of iron-stone raised amounting to 8,000 tons and 1,454 tons respectively.

The coal raised according to the "Mineral Statistics" in the years 1878 and 1879 is in excess of that of the Inspectors, and is given respectively at 4,540 tons and 4,697 tons.

* Reports of H.M. Inspectors of Mines.

CHAPTER IV.

LANCASHIRE COAL-FIELD.

General Description of Coal-field—Principal Coal Seams Wigan and Burnley Districts—Analyses and Production of Coal—Deep Pits at Rosebridge Collieries, Wigan, and Ashton Moss, near Manchester—Pemberton Colliery, General Arrangements—Coal Washing Apparatus—Distribution of Coal—Bridgewater Navigation—Sent Coastwise and Exported—Population employed in Coal Mining—Price of Coal and Cost of Production—Resources of Coal-field, and probable duration.

The Lancashire Coal-field. — This important coal-bearing tract, most irregular in outline and greatly disturbed by faults, has an estimated area of 217 square miles. The chief centres of activity are Prescot, Saint Helen's, Wigan, Bolton, Bury and Manchester, and the isolated tract of Burnley. The South Lancashire area of the coal-field, extending from Bickerstaffe to Staleybridge, is thirty-two miles in length, its average breadth being about six miles. The number of seams of workable coal, as also the character of the strata in which they occur, vary considerably in different parts of the area; thus in the neighbourhood of Saint Helen's the number of coal seams exceeding two feet are 13, compared with 17 in the Wigan and 18 in the Manchester district; a general thickening out of the coal measures taking place towards the N.N.E., the same coal seams being found further apart at Saint Helen's than at Prescot, and at Wigan than at Saint Helen's.

The coal measures are divided into Upper, Middle and Lower. The Upper form the Manchester coal-field, and include the Ardwick limestone series, containing numerous fish remains overlying the Bradford Four-foot coal. The Middle coal measures, with a section of 3,500 feet, containing all the important seams of coal, from the Worsley Four-foot coal to the Arley mine. The Lower or Ganister series, consisting of flags, shales and thin coals. The seams of the Middle coal measures vary from 3 to 9 feet in thickness, and most of them can be traced over the whole district under different names; for example, the "Little Delf" of Saint

Helen's is the Arley Mine of Wigan, the "Riley Mine" of Bolton, and the "Dogshaw Mine" of Bury. It is the lowest coal bed of the Middle series, and of great economic value.* The following are the more important seams wrought in the Wigan area of the coal-field, with their respective average thickness:—

		Ft.	In.
Four-foot Coal of Red Rock Bridge		4	0
Ince Yard Coal		3	0
Ince Four-foot Coal		3	7
Ince Seven-foot Coal (with parting)		7	0
Furnace Mine (with parting)		4	7
Pemberton Five-foot Mine		5	2
Pemberton Four-foot Mine		4	6
Wigan Five-foot (inferior)		4	6
Cannel Best Gas Coal	from 1 to	3	0
King Coal		3	10
Yard Coal		3	0
Bone Coal		2	3
Smith Coal (Rushy Park)		3	6
Arley Mine		4	0

The last-named seam being the next in value to the Cannel.

In the northern and eastern portions of the district and at Upholland, near Wigan, in the lower coal measures, two thin seams of coal are worked, the one known as the "Upper Mountain Mine" in the Oldham district, from 14 to 16 inches thick, and a second, the "Lower Mountain Mine," or "Ganister Coal," varying in thickness from 18 to 30 inches, the two seams separated by intervening strata, amounting to from 60 to 75 yards. The other districts of importance are the coal areas in the neighbourhood of Manchester and the Burnley coal-field; the former lies to the north-east of Manchester, four and a half miles in length, its greatest breadth not exceeding one and a half miles: the latter, small but rich coal basin of Burnley, lying further to the north of the main coal-field. In both these districts important and valuable seams of coal occur. The following gives generally those in the Burnley district, with their average thickness:—

	Ft.	In.
Doghole Coal	6	0
Kershaw Coal	3	0
Shell Coal	2	6
Main Coal	5	0
Maiden Coal	3	0
Lower Yard or Five-foot Coal	5	0
Lower Bottom or Four-foot Coal	3	6

* Professor Hull's "Coal-fields," 4th ed., p. 200.

		Ft.	In.
Impure Cannel		2	6
Thin Coal (and Fish Bed)		2	9
Great Mine	Coal, 28 in. Shale, 12 ,, Coal, 19 ,,	4	0
China Bed		2	0
Danchy Bed		2	0
Fulledge Main Coal or Arley Mine		4	0

Below the Fulledge Coal, in the lower coal measure, occurs the upper and lower Mountain Mines, the latter, "Ganister Coal," having a thickness of about four feet, the former being about two feet. Bands of ironstone occur in this district, and were formerly worked.

Analyses of Lancashire Coal.—The second Report of Coals suited to the Steam Navy affords very valuable information of the economical value of the Lancashire coal.*

Of the following well-known seams worked in the Wigan district, the annexed particulars are gathered :—

Balcarres Arley Mine.—Described "as a semi-bituminous coal, the vein at a depth of 212 yards from the surface being 5 feet 6 inches thick, and regular. The coal on examination was found to light easily and burn freely, but with the evolution of much smoke during the time of combustion. The amount of ash left was rather considerable, but the quantity of clinker formed was so small that at the expiration of eight hours from the time of lighting the fire the draughtways between the bars remained nearly as clear as before the commencement of the operation. The small quantity of clinker formed was very fusible, and adhered to the bars."

Balcarres Five-foot Mine.—This mine is also situated in the parish of Wigan. The vein is 5 feet 4 inches thick, and has been found to be regular as far as proved. This coal, like the former, was found to light readily, and blows off the steam rapidly, but gives a hard clinker, which adheres so firmly to the bars as to interfere materially with the maintenance of a clear fire. The coal gives off much smoke during combustion, and leaves a considerable amount of reddish ash.

The Balcarres Haigh Yard Mine.—The coal of this seam occurs at a depth of 98 yards from the surface, is 34½ inches in thickness, and very regular, and yields a free burning coal.

* De la Beche and Playfair, 1851.

The coal resembles in appearance the two last coals referred to, and was found during the experiments to burn in a nearly similar way, with the exception of its being consumed rather less rapidly and more steadily than the other specimens. The clinker was found to be small in quantity, but extremely fusible, and by melting on the bars obstructed the draught.

Blackley Hurst Four-foot Vein and Three-foot Vein.— The average thickness of the former is 3 feet 10½ inches, while the latter is usually an inch less than its name implies. The Four-foot Vein is mined at a depth of 60 yards, and the Three-foot Vein at a depth of 140 yards from surface. The coal is described as clean and durable, and has been largely used by the Scotch and Irish steam packets, and it further appears that a mixture of these two veins furnished a supply of fuel to the Halifax and Boston mail steamers for a considerable period. This coal has also been employed for the manufacture of gas, and it was observed during the experiments to be slightly bituminous and rather fragile, yielding much smoke and depositing a considerable amount of soot. Little ash and clinker were, however, left, the latter being of reddish colour and very hard. The following shows the mean composition of average samples of these coals: *—

Constituents.	BALCARRES COLLIERY.			Blackley Hurst Four-foot Mine.
	Arley, five feet six in.	Five-foot Mine.	Haigh Yard Mine.	
Carbon	83·54	74·21	82·26	82·01
Hydrogen	5·24	5·03	5·47	5·55
Nitrogen	0·98	0·77	1·25	1·68
Sulphur	1·05	2·09	1·48	1·43
Oxygen	5·87	8·69	5·64	5·28
Ash	3·32	9·21	3·90	4·05
	100·00	100·00	100·00	100·00
Specific gravity	1·26	1·26	1·28	1·26
Coke per cent.	62·89	55·90	66·09	57·84

Other analyses of coal raised in the Wigan district show the

* Second Report, "Coals suited to the Steam Navy," by De la Beche and Playfair, p. 7.

following constituents, the samples examined being from seams in the Ince Hall Collieries, and employed for steam, domestic purposes and gas manufacture. The analysis in the last column is of the Cannel coal worked in the collieries at Walthen House, two miles from Wigan, of Messrs. W. H. Brancker & Co., and extensively used for gas-making, with the exception of small quantities used for household purposes. The principal market for this coal is Liverpool, distant 33 miles from the mine. The results of analyses are thus tabulated:—

Constituents.	INCE HALL COLLIERIES.			Cannel Seam.
	Arley Four-foot.	Pemberton Four-foot.	Pemberton Five-foot.	
Carbon . . .	82·61	77·01	68·72	79·23
Hydrogen . . .	5·86	3·93	4·76	6·08
Nitrogen . .	1·76	1·40	2·20	1·18
Sulphur . . .	·80	1·05	1·35	1·43
Oxygen . . .	7·44	5·52	8·63	7·24
Ash	1·53	11·09	14·34	4·84
	100·00	100·00	100·00	100·00
Specific gravity .	1·272	1·276	1·269	1·23
Coke per cent. . .	64·00	57·10	56·50	60·33

The coals worked by the Moss Hall Company, whose collieries are situated near Wigan, have also been investigated. The following coals are thus described:—

The Pemberton Four-foot Coal, raised from the Moss Hall Colliery, being obtained from a depth of 208 yards from the surface, the vein exhibiting great regularity, and 4 feet 6 inches thick; the specimen examined being a bright coal, with a cubical fracture, free from iron pyrites, and containing but little shaly matter or mineralized charcoal.

The Pemberton Five-foot Coal is obtained from a colliery situated in the immediate neighbourhood of the preceding, and is described as "hard, burning moderately freely, and very hot."

The New Main Coal, worked by the same Company at a depth of 110 yards, the vein, which is 4 feet 6 inches thick, being divided in the middle by four inches of metal. The coals from this vein are described as "moderately hard, free burning,

and producing a great heat." This, like the two previous varieties in the experiments made, was found to yield similar results. The annexed shows the mean composition of average samples of the coals referred to:—

Constituents.	Pemberton Four-foot.	Pemberton Five-foot.	Pemberton New Mine.
Carbon	75·53	76·16	77·50
Hydrogen . . .	4·82	5·35	4·84
Nitrogen . . .	2·05	1·29	·98
Sulphur . . .	3·04	1·05	1·36
Oxygen	7·98	10·13	12·16
Ash	6·58	6·02	3·16
	100·00	100·00	100·00
Specific gravity .	1·258	1·283	1·278
Coke per cent. . .	55·70	56·10	57·70

The coal seams wrought in the Haydock Collieries of Messrs. Richard Evans & Co., situated in the parish of Ashton in Makerfield, near Warrington, and of which analyses are published, exhibit considerable variety, and are thus described:—

The Rushy Park Coals are obtained at a depth of 260 yards from the surface, the seam having a thickness of 4 feet 8 inches. These coals are employed for the generation of steam and other furnace purposes; the specimen examined was bright, with a cubical fracture, and contained rather large quantities of iron pyrites.

The Haydock Little Delf, extracted from the same colliery, at a depth of 320 feet from the surface; the vein is 3 feet 6 inches thick, the coal being chiefly employed for smith's use and coking; this coal closely resembles the foregoing, but is more bituminous, softer, and less bright, contains large quantities of white shale and mineralized charcoal, although but little iron pyrites was observed.

The Haydock Higher Florida Coals, obtained from the colliery of the same name, situated in the same parish as the two preceding mines, is obtained from a vein 4 feet 4 inches thick, at a depth of 250 yards from the surface. The coals are described as "clean, hot and durable," and are largely used by the ocean steamers from the Mersey and at the saltworks in

Cheshire. The coal is very brilliant, and has a cubical fracture, but contains considerable quantities of white shale and iron pyrites, particularly on the planes of cleavage, where a little brown coal and mineralized charcoal are also occasionally met with.

The Florida Main Seam.—These coals are extracted from the same colliery as the foregoing, and are raised from a vein about 10 yards below the higher seam. The roof is composed of fire-clay and shale, and the underlying strata consist of dark shale and grit-stone. The vein is 6 feet in thickness and is tolerably regular.

The composition of average samples of the Haydock seams is as follows:—

Constituents.	Rushy Park.	Little Delf.	Higher Florida.	Florida Main Seam.
Carbon	77·65	77·91	77·33	77·49
Hydrogen . . .	5·53	5·16	5·56	5·50
Nitrogen . .	·50	·54	1·01	1·27
Sulphur	1·73	·52	1·03	0·88
Oxygen . . .	10·91	10·65	12·02	12·84
Ash	3·68	3·42	3·05	2·02
	100·00	98·20	100·00	100·00
Specific gravity .	1·323	1·257	1.218	1·267
Coke per cent. . .	59·40	58·10	57·10	54·40

Another analysis of the Rushy Park Coal, described "as slightly caking; lustre of coke, semi-transparent;" showing the following composition:—

RESULTS TABULATED.

Carbon	75·81
Hydrogen	5·22
Oxygen	11·14
Nitrogen	1·93
Sulphur	0·90
Ash	5·00
	100·00

The specific gravity of this sample was 1·279, and the yield of coke per cent. 65·50.

Production of Coal.—The early history of coal-mining in Lancashire and the production of coal is very obscure. It is generally known, however, that towards the close of the past century the coal produced was not considerable, and further, that the construction of the Bridgewater Canal, bringing many of the great centres of industry into communication, greatly contributed to the development of the resources of the coal-field. The above great enterprise was commenced about the year 1759, and was designed and constructed by the celebrated engineer, James Brindley, connecting Worsley with Manchester, and furnishing an important outlet for the coal of that section of the Lancashire coal-fields. The canal was afterwards extended to Liverpool, and in 1762 an Act of Parliament was obtained to extend the canal to the tideway in the river Mersey. The Sankey Brook Canal was formed and opened a few years previously, between 1755 and 1759, connecting the coal-field of Saint Helen's with the river Mersey.

In the year 1854 * appeared an interesting paper by Mr. J. Dickinson, H.M. Inspector of Mines, on the Lancashire, Cheshire and North Wales coal-field, in which it is stated regarding Lancashire, that the coal produced in 1852 amounted to 8,255,000 tons, from 334 collieries, the pits being of various depths, up to 520 yards.† Deeper coals were at that time worked by incline planes, from the bottom of shafts, to a depth from surface of 600 yards. The 334 collieries above referred to were worked by 679 pits, the average depth being about 118 yards.

These depths are now greatly exceeded. At Rosebridge Colliery in the Wigan district, coal is being won at a depth of 815 yards from the surface.‡ Recently, at the Ashton Moss Colliery, Auldenshaw, near Manchester, the "Great Mine," a seam of coal 6 feet thick, has been reached at a depth of 895 yards from the surface, or 897 yards including the seam itself. As far back as the year 1874, the Ashton Moss Colliery Company commenced sinking operations, with the view of finding the Four-foot Mine, which was being worked in other parts of the coal-field. At a depth of 450 yards the mine was proved,

* "Memoirs of the Literary and Philosophical Society of Manchester," vol. xii. p. 71.

† Two pits at the Pendleton Colliery (1852).

‡ August, 1880.

and several headings were driven by way of testing the bed, which, however, was found to be not of sufficient thickness to be workable. The proprietors now determined to sink a shaft 250 yards deeper, in all 700 yards. This depth, greater than that of the Astley Deep pit at Dukinfield (686 yards), in the adjoining county of Cheshire, having been reached, and not having overtaken any coal of a workable character, the engineers now directed that borings should be made; the results were encouraging, and orders were given to sink further, and on Saturday, 5th March, 1881, six years after the ground was first broken, the workers reached the "Great Mine" above referred to. This seam is believed to be a continuation, without any intervening fault, of the seams which are at present being worked on the east side of Manchester.

At a depth of 950 yards lies the "Roger Mine," 4 feet thick, and below this are supposed to exist several workable seams of coal, including the Black Mine and the Cannel Mine, both of which are got at Ashton. The coal is a house-fire coal, with coking properties, and is most valuable for position, being so near the large centres of population, available alike for quantity and excellence. The field that can be worked by the Company is about 2,000 acres in extent, from Guide Bridge to Droylsden on one side, and extending from Fairfield to Ashton on the other. A second shaft is now being sunk; being indeed but 200 yards short of the first shaft, and when working operations have fairly begun the mines are calculated to yield from 1,500 to 2,000 tons per day, and plant is being put down with that view. In the sinking operations the miners encountered no less than sixty seams or strata of coal, cannel, or shale, varying from 3 inches to more than 2 feet in thickness, but none until now of a workable character. The temperature, taken at a depth of 860 yards, was 78° Fahr. The "Great Mine," which has just been proved, has been worked from the outcrop to within a distance of 2,000 yards at the Lord's Field Colliery, and about 1,000 yards by the Dukinfield Coal and Cannel Company, "fair rise and dip." The first-named pit pierces the seam vertically at a depth of 130 yards, and the Chapel and Dewsnap Pits of the latter Company strike it at about 250 yards.

In comparison with other pits the Ashton Moss Pit is the deepest in England. The sinkings and borings have penetrated

to a depth of 1,050 yards; the sinkings alone have reached 895 yards, and this will soon be increased to 950 yards. Hitherto the Astley Deep Pit at Dukinfield (686 yards), the Rose Bridge Pit at Wigan, and the Moss Pit, situated in the same locality, extending to a depth of about 820 yards, were regarded as the deepest coal-pits in the kingdom.

Even these great depths are exceeded in the mining districts of continental countries; the deepest perpendicular shaft at present existing is that of Adalbert, at Prizbram, in Bohemia, which has reached the depth of 2,100 metres, or 1,096 yards, though there are others, not quite perpendicular, which are still deeper. The Rock-salt bore-hole, at Spesenberg, near Berlin, was carried down 4,175 feet some few years ago, and a coal-mine at Viviers, Belgium, is now 3,542 feet. Two other shafts in Belgium, at Gilly, are sunk to the depth of 2,847 feet, and from these an exploring shaft was carried 666 feet further, though it was unsuccessful as regards the finding of the expected seam.

The deepest shaft in Prussian mining is the Samson Shaft at the Oberhartz Lead and Silver Works in Hanover, which is 2,437 feet. France has nothing beyond 1,881 feet, at a colliery at Ronchamp. There is only one case on record where a depth exceeding one mile from the earth's surface has been reached; viz., at the Artesian well at Potsdam, Missouri, in the United States of America, where the chisels have been carried down to 5,500 feet, or 1 mile 220 feet.

Resuming with the returns of coal produce in Lancashire, in the following table will be found the number of collieries and output of coal in the North and East or Manchester district; and the Western district (Saint Helen's and Wigan), together with the total number of collieries and produce of coal, from which it will be seen, that since the year 1854 the output of the collieries of Lancashire have increased a hundredfold; and it may be generally observed, that during the year 1880 the coal trade of Lancashire was carried on under very unfavourable circumstances. In the beginning of the year colliery proprietors largely increased their output, due to the revival of trade which set in towards the close of the previous year. These hopes were not realised, and the increased production became a burden on the market. During the last two months of the year, however, a better demand arose for coal; this was met by increased output and better prices.

Year.	NORTH AND EAST DISTRICT.		WESTERN DISTRICT.		TOTAL COAL.	
	No. of Collieries.	Coal raised.	No. of Collieries.	Coal raised.	No. of Collieries.	Lancashire.
		Tons.		Tons.		Tons.
1854	...	...	...	...	340	9,080,500
1855	...	...	...	...	357	8,950,000
1856	248	...	111	...	359	8,950,000
1857	247	...	112	...	359	8,565,000
1858	273	...	107	...	380	8,050,000
1859	272	5,750,000	109	4,900,000	381	10,650,000
1860	266	5,750,000	105	5,600,000	371	11,350,000
1861	269	5,950,000	104	6,245,000	373	12,195,000
1862	272	4,975,500	107	5,622,000	379	10,597,500
1863	280	5,325,500	99	5,550,000	379	10,875,500
1864	276	5,900,000	103	5,630,000	379	11,530,000
1865	249	6,312,000	93	5,650,000	342	11,962,000
1866	251	6,570,000	95	5,750,500	346	12,320,500
1867	254	6,844,000	99	5,997,500	353	12,841,500
1868	293	7,053,000	93	5,747,500	386	12,800,500
1869	299	7,020,000	93	6,975,500	392	13,995,500
1870	298	7,055,500	87	6,755,100	385	13,810,600
1871	287	7,576,000	89	6,275,000	376	13,851,000
1872	324	9,363,236	98	...*	422	16,363,236
1873	325	9,500,000	160	7,500,000	485	17,000,000
1874	376	8,095,570	182	7,442,950	558	15,538,520
1875	400	8,825,798	188	8,250,246	588	17,076,044
1876	385	8,265,000	174	9,125,000	559	17,390,000
1877	342	8,735,055	175	8,886,476	517	17,621,531
1878	344	8,634,500	178	9,425,525	522	18,060,025
1879	362	9,020,045	179	9,591,700	541	18,612,345
1880	311	9,519,858	166	9,600,436	477	19,120,294

During the years 1879 and 1880, among the many extensive companies raising coal in Lancashire may be mentioned the Wigan Coal and Iron Co., who produce annually from their numerous collieries upwards of one and a half million of tons; the Messrs. Andrew Knowles and Sons, and the Bridgewater Trustees, each raising nearly one million tons.

The yield of Cannel coal is obtainable for a few years only, from 1857 to 1862, and was as follows; these quantities being included in the above totals for each of those years:—

CANNEL COAL PRODUCED IN LANCASHIRE.

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1857	300,000	1860	350,000
1858	275,000	1861	450,000
1859	295,000	1862	332,000

* Included in the return of North Wales, and estimated at 7,000,000 tons.

Before proceeding further this will be a fitting place to give an account of some of the mechanical arrangements employed in an extensive Lancashire colliery; that of "Pemberton" of Messrs. Blundell, affords an interesting illustration, and was visited in the autumn of 1879 by the members of the Iron and Steel Institute, in whose Journal the following account appears:—

"The Pemberton Colliery has two shafts, sunk to a depth of 624 yards,—a downcast and an upcast. The downcast is 17 feet 4 inches in diameter at the top and 16 feet at the bottom. The shafts were sunk by means of two pairs of horizontal engines, with cylinders 16 inches diameter and 3 feet stroke. Down each side of the shaft run pairs of railway metals, which form guides for the cages. The cages each hold six tubs, are made of steel, and weigh 28½ cwts. The tubs also are made of steel, weigh 3¾ cwts., and carry about 7¼ cwt. of coal. The ropes are steel, and taper from 1⅝ inch to 1¾ inch, and weigh about 3 tons. The heapsteads are well arranged and substantially built; one of iron, and the other of iron and stone combined. The screening arrangements are well planned. After the round coal has passed the ordinary screen, the remainder falls through an iron hopper into a long tube containing an 18-inch worm or creeper, along which the coal is carried into a well, whence it is mechanically lifted into the apparatus house, and passing through revolving screens, is discharged into waggons, in its various sizes.

"The coal-washing apparatus is of the ordinary kind, the washed coal being converted into coke on the premises. The engine-house is a fine building, containing two pairs of 36-inch cylinder horizontal winding engines, with 6-feet stroke. The winding drums are conical in form, with a maximum diameter of 30 feet 6 inches, and a minimum diameter of 19 feet, arranged for winding from the depth of 624 yards in 22 revolutions. The centre lines of the pulleys are on the flat part of the top of the drums, and consequently there is no chance of the rope slipping, while an additional protection is afforded by the coiling of the rope in a spiral groove. The pulleys are 18 feet in diameter. The boilers are 16 in number, each 28 feet long, and having two flues, each 2 feet 10 inches in diameter. A capstan engine is placed on the ground floor of the engine-house, which can be adapted to either shaft in case of emergency. For this purpose centre pulleys have been fixed in the head-gear.

The colliery is ventilated by a Guibal fan, constructed of steel, and measuring 46 feet in diameter and 15 feet in width. The length of the shaft is 19 feet 3 inches, and its diameter in the centre 16½ inches, and at the pedestal end 12 inches. At the crank end the bearings are 18 inches long, and engines have been specially adapted to work the fan. There are two cylinders 36 inches in diameter, with a stroke of 3 feet 6 inches. One of the cylinders is sufficient to work the fan, but the other can be applied in a few minutes without interfering to any perceptible extent with the ventilation. The shaft is covered at the top with two doors, and the air enters the fan-house by means of a culvert. At the top of the drift, between the fan and the shaft, there is an escape chimney provided with four doors, so that in case of an explosion the blast would pass through these doors, and also through the door in the pit-scaffold, without injuring the fan.

"The fan is calculated to produce 247,000 cubic feet per minute at 53 revolutions and 3¾-inch water-gauge. The fan-engine was constructed by Messrs. Baker and Valiant, of Wigan, and the fan by the Staveley Iron Company. At this colliery has been introduced a new system of working the coal by means of compressed air, invented by Mr. E. Reuss. In this system a circular hole is bored into the face of the coal for the reception of a cast-iron cartridge, which is connected with a powerful hand air-compressor. The cartridges are simply hollow castings, about 14 inches long and 3 inches in diameter, having one end solid and the other tapped to receive the tubing. The cartridge having been inserted in the coal, the air-compressor is started, and when the required pressure has been reached the cartridge bursts with a sharp report, bringing down the coal ready for loading."

Distribution of Coal. — Foremost amongst the railways in the movement of coal, the produce of Lancashire, is the London and North-Western, whose system traverses the coal-field in all directions. In the year 1854 this system carried from Lancashire 1,248,461 tons, increased in 1859 to 1,411,000 tons. Since 1859 the total weight of coal carried, distinguishing that passed on other lines from that carried on the North-Western system, will be seen in the subjoined table, amounting in the last-named year to 7,024,080 tons, of which 5,676,094 tons were conveyed to stations on the London and North-Western Railway, and 1,347,986 tons to stations on the lines of other companies.

Years.	To Stations on London and North-Western Railway.	To Stations on other Companies' Lines.	Total.
	Tons.	Tons.	Tons.
1859	...	...	1,411,000
1862	...	...	1,641,391
1863	...	...	1,796,035
1864	...	...	2,557,087
1865	...	...	3,440,778
1866	...	...	3,321,737
1868	3,375,597	366,378	3,741,975
1869	3,790,482	420,598	4,211,080
1870	4,350,534	617,251	4,967,785
1871	4,612,476	824,574	5,437,050
1872	5,127,663	570,595	5,698,258
1873	4,618,324	796,739	5,415,063
1874	3,862,609	1,043,885	4,906,494
1875	4,604,432	1,230,726	5,835,158
1876	4,629,689	1,349,685	5,979,374
1877	4,812,141	1,332,143	6,144,284
1878	4,951,485	1,263,974	6,215,459
1879	5,464,701	1,421,252	6,885,953
1880	5,676,094	1,347,986	7,024,080

The Lancashire and Yorkshire Railway contributes largely to the movement of Lancashire coal; the quantity in 1869 was 2,261,511 tons, increasing yearly, as shown by the annexed statement:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1869	2,261,511	1876	3,360,041
1872	2,874,637	1877	3,556,192
1873	2,781,805	1878	3,648,663
1874	2,859,742	1879	3,915,411
1875	3,285,434	1880	4,120,572

The Manchester, Sheffield and Lincolnshire Railway also carries coal from this coal-field, principally to Manchester, Ardwick, Gorton, Guide Bridge, Ashton, and Staleybridge; the quantities received and forwarded are as follows:—

Year.	Received.	Forwarded.	Year.	Received.	Forwarded.
	Tons.	Tons.		Tons.	Tons.
1860	99,922	11,581	1865	63,152	1,285
1861	107,834	15,228	1866	80,428	3,594
1862	74,192	19,637	1867	39,870	6,938
1863	79,287	307	1868	24,659	2,708
1864	63,577	571	1869	18,191	1,590

The returns of later years appear in a different form and show the quantities carried by the same railway system from Ashton-under-Lyne and Wigan :—

Year.	Wigan.	Ashton-under-Lyne.	Total.
	Tons.	Tons.	Tons.
1870	1,672	12,255	13,927
1871	2,864	9,613	12,477
1872	15,357	13,783	29,140
1873	9,896	17,532	27,428
1874	10,173	12,487	22,504
1875	6,346	17,857	24,203
1876	32,122	20,453	52,575
1877	23,218	38,590	61,808
1878	21,262	24,667	45,929
1879	27,404	29,532	56,936
1880	23,066	32,842	55,908

Following the distribution of coal by canal in Lancashire, the first return met with of the coal traffic of the Bridgewater Navigation is for the year 1868,* when 501,514 tons were conveyed from the Worsley coal-field; 411,191 tons from the Wigan coal-field, and 5,507 tons from the Saint Helen's district; giving an aggregate carried of 918,212 tons. The importance of the Bridgewater Canals, and the great facilities they afforded at an early period for the conveyance of merchandise and minerals long before the introduction of railways, is thus referred to by a local historian, Aitkin :—"When the Duke of Bridgewater undertook this great design (the construction of the Bridgewater Canal), the price of carriage on the river navigation was 12*s.* the ton from Manchester to Liverpool, while that of land carriage was 40*s.* the ton. The Duke's charge on his canal was limited by Statute to 16*s.*, and together with this vast difference it had all the speed and regularity of land carriage. The articles conveyed by it were likewise much more numerous than those by river navigation. Besides manufactured goods and their raw materials, coals from the Duke's own pits were deposited in yards at various parts of the canal for the supply of Cheshire." †

The only other statement throwing light on the coal traffic

* Coal Commission Report, vol. iii., p. 81.

† Aitkin's "Description of the Country round Manchester," p. 116.

of the Bridgewater Navigation Company is for the years 1878, 1879, and 1880 when the quantities carried were as follows:—

Districts.	1878.	1879.	1880.
	Tons.	Tons.	Tons.
Received from the Wigan District by the Leeds and Liverpool Canal	313,000	260,000	315,000
From Worsley and other Collieries	507,000	498,000	512,000
Total .	820,000	758,000	827,000

The Leeds and Liverpool Canal also carries large quantities of coal, for shipment in all directions from Lancashire and Yorkshire, amounting in 1878 to 1,150,000 tons, 1,186,000 tons in 1879, and 1,301,105 tons in 1880.

A writer in the *Colliery Guardian*,* referring to the small amount of coal shipments from Lancashire, remarks, "There are few coal-fields whose trade it is more difficult to give an account of than Lancashire. The fact that it is the busiest and most populous county in the United Kingdom no doubt accounts for the fact, that the consumption of coal is almost entirely local. There is no coal-field that exports less coal, nor is this surprising, for in previous years when the production was less than it is now, large quantities had to be imported. Now, however, the local supply has risen to the requirements. As to the chief sources of consumption they are almost too numerous to mention. Some of the largest ironworks in the kingdom are in Lancashire, but those do not rely on Lancashire coal. Hence the supply and demand are not so directly affected by the manufacture of crude iron as might at first sight appear. On the other hand, the textile industries of Lancashire are the largest in the kingdom, but cotton-mills do not consume much coal; and the years of greatest coal production have been those when the mills were least active. The general and domestic consumption, however, must be large:—within the radius of local consumption, nearly equal to that of the London district; and we know that the general and domestic consumption of

* "Ten Years of Coal Mining," Lancashire. August 20, 1880, p. 291.

London is about nine millions—one-half of the total production of Lancashire. The population of Lancashire, however, is pre-eminently an industrial one, and it is not difficult to understand how her teeming industries can consume as much more coal as the general and domestic consumption. Nearly a million tons are shipped at Liverpool, but compared with other districts having access to the sea, its coal shipments are remarkably small.

The total shipments of coal, coastwise and to foreign countries, from Lancashire, in which the shipments from Cheshire are included, were as follows, in each year given :—

Year.	Coastwise.	Exported.	Total.
	Tons.	Tons.	Tons.
1842	165,428	125,357	290,785
1845	165,018	125,852	290,870
1850	279,364	264,892	544,256
1860	358,654	604,168	962,822
1870	580,726	561,567	1,142,293
1875	582,989	717,104	1,240,093
1876	503,555	730,750	1,234,305
1877	512,596	721,560	1,234,156
1878	569,885	624,924	1,149,809
1879	669,481	563,693	1,233,174
1880	753,804	610,572	1,364,376

In the year 1879 the details of the coal shipments, coastwise and exported, were as follows, from Lancashire and Cheshire :—

Ports.	Shipments Coastwise.	Shipments Foreign.	Total Shipments.
	Tons.	Tons.	Tons.
Chester . . .	53,455	5,855	59,310
Liverpool . . .	459,504	549,742	1,009,246
Runcorn . .	55,165	1,190	56,355
Preston . . .	16,348	...	16,348
Fleetwood . .	84,721	6,030	90,751
Barrow . . .	...	626	626
Lancaster . .	288	250	538
Total .	669,481	563,693	1,233,174

The great bulk of the above coal being despatched from Liverpool, the chief port of shipment, it will be interesting to follow the increase of shipments, coastwise and foreign, from that port. It must be borne in mind, however, that although the

great bulk of the coal is derived from the Lancashire coal-fields, that shipped at Birkenhead, included in the port of Liverpool, is derived from the Cheshire and North Wales coal-fields, while a small quantity is received from Yorkshire. The shipments are as follows from Liverpool:—

Year.	Coastwise.	Foreign.	Total.
	Tons.	Tons.	Tons.
1842	56,218	117,718	173,936
1845	29,289	123,456	152,745
1847	15,390	106,197	111,587
1850	117,209	260,943	378,152
1852	105,932	277,645	383,577
1855	105,030	424,059	529,089
1858	166,952	474,713	641,665
1860	160,238	590,128	750,366
1865	130,566	616,976	747,542
1870	141,353	531,719	673,072
1871	377,209	688,085	1,065,294
1872	357,940	738,489	1,096,429
1873	388,520	591,368	979,888
1874	286,001	717,420	1,003,421
1875	334,502	704,496	1,038,998
1876	303,269	723,532	1,026,801
1877	296.731	715,594	1,012,325
1878	362,381	614,741	977,122
1879	459,504	549,742	1,009,246
1880	487,547	568,402	1,055,949

The total declared value of coal exported in 1880 from Liverpool to foreign countries was £319,313, giving an average value of 11*s.* 6*d.* per ton, compared with £608,196, the value of coal sent to foreign countries in 1872, giving an average of 16*s.* 6*d.* per ton.

Population Employed in Coal-Mining.—The total number of male persons employed in coal-mining in the year 1854 was 28,834 of all ages. The extensive collieries of Messrs. Andrew Knowles and Sons at this period were producing daily about two thousand four hundred tons of coal. It further appears that in Lancashire, in the same year, an ordinary collier in a Four-foot seam worked about four tons a-day. Each collier having an assistant, called a drawer, who trams the coal to the horse-road or the shaft, this reduces the get per collier to two tons per day, while the holidays usually accorded to underground workmen further reduced the average get per person to the amount above stated. In 1864, for the first time, H.M. Inspectors ascertained

the number of persons employed in and about the coal-mines of Great Britain, and in that year the number in North and East Lancashire, known as the Manchester district, was 23,525, the coal raised amounting to 5,998,875 tons. The Western division of Lancashire, including the Wigan and Saint Helen's districts, being grouped with North Wales, the separate numbers engaged are not distinguished before the year 1873.

The following are the numbers of persons employed in North and East Lancashire and North Wales between the years 1864 and 1872, with the quantities of coal raised in each year and the average produce per man :—

Year.	Number Employed.	Coal Raised.	Average per Man.
		Tons.	Tons.
1864	23,525	5,998,875	255
1865	23,525	6,312,000	268
1866	25,440	6,774,000	266
1867	26,820	6,844,000	255
1868	26,360	7,053,000	267
1869	26,190	7,020,000	268
1870	26,200	7,030,000	268
1871	26,110	7,575,800	290
1872	28,657	9,363,236	326

In the year 1873 "The Coal Mines Regulation Act" came into operation, and since that date very complete information is found in H.M. Inspectors of Coal Mines' Reports, distinguishing the number engaged underground and above ground and their respective ages. In the annexed table is given the numbers so employed in the North and East Lancashire district, with the output of coals * and average produce per man :—

Year.	Employed.		Total Employed.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	26,429	5,453	31,882	8,063,855	253
1874	27,166	5,662	32,828	8,063,974	245
1875	27,305	5,701	33,006	8,881,137	263
1876	25,048	5,334	30,382	8,264,179	272
1877	24,154	5,190	29,344	8,741,387	298
1878	24,726	5,063	29,789	8,633,839	298
1879	25,495	5,262	30,757	8,993,697	292
1880	25,552	5,445	30,997	9,519,858	307

* H.M. Inspectors of Mines Reports.

The corresponding figures for the Western district, including Wigan and Saint Helen's, being as follows:—

Year.	EMPLOYED. Under Ground.	EMPLOYED. Above Ground.	Total Employed.	Coal Raised.	Average per Man.
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	22,753	6,571	29,324	7,818,112	266
1874	22,709	6,813	29,522	7,446,725	252
1875	24,314	7,224	31,538	9,048,914	287
1876	23,230	6,963	30,193	9,091,374	301
1877	22,812	6,734	29,546	8,952,425	303
1878	23,177	6,203	29,380	9,427,572	320
1879	23,288	6,028	29,316	9,562,170	325
1880	23,314	5,932	29,246	9,600,436	328

Summarising the two districts, the following shows the total number of persons working underground and above ground in the Lancashire coal-fields, with the coal raised and the average produce per man:—

Year.	EMPLOYED. Under Ground.	EMPLOYED. Above Ground.	Total Employed.	Coal Raised.	Average per Man.
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	49,182	12,024	61,206	15,881,967	260
1874	49,875	12,475	62,350	15,510,699	248
1875	51,619	12,925	64,544	17,930,051	277
1876	48,278	12,297	60,575	17,455,553	288
1877	56,966	11,924	58,890	17,693,812	291
1878	47,903	11,266	59,169	18,061,411	305
1879	48,783	11,290	60,073	18,555,867	309
1880	48,866	11,377	60,243	19,120,294	327

In 1870 the total coal produced in Lancashire was 13,810,600 tons, and in 1880 the returns show an increase of 5,309,694 tons, giving an increase of nearly 38 per cent. in a period of ten years; indeed, in no other coal-field has the production increased so rapidly. When in 1872 and 1873 the demand for coal became so considerable, many new shafts were sunk and old pits re-opened to meet the requirements of the time, and when the temporary pressure was met the number of workings was reduced, prices having fallen, rendering the continuance of operations unproductive. Now, however, it appears that those collieries which continued at work during the years of depression are

producing coal in larger quantities than they did in previous years when prices were better than they at present are.

From the above figures it appears that the individual efficiency of the miner has greatly increased in Lancashire in recent years; the average output per man rising from 260 tons in 1873 to 327 tons in 1880, equivalent to an increase of 25 per cent.

The respective ages of all employed in coal-mining in Lancashire, as previously stated, amounted to 60,073 in the year 1879; the details appear in the annexed table:—

All Ages.	Males and Females.	NORTH AND EAST.		WEST.		Total.
		Under Ground.	Above Ground.	Under Ground.	Above Ground.	
		Nos.	Nos.	Nos.	Nos.	Nos.
From 10 to 12	Males	191	...	...	...	191
,, 12 to 13	,,	485	...	263	...	748
,, 10 to 13	,,	...	118	...	23	141
,, 13 to 16	,,	2,302	291	1,817	366	4,776
,, 13 to 16	Females	...	9	...	120	129
Above 16	Males	22,517	4,616	21,208	4,269	52,610
,, ,,	Females	...	228	...	1,250	1,478
	Total .	25,495	5,262	23,288	6,028	60,073

Price of Coal and Cost of Production.—About the year 1860 the cost of getting coal on the average was estimated at 4*s*. 6*d*. per ton for ordinary coal, and 6*s*. 6*d*. for cannel coal, the former selling at bank at 6*s*. 3*d*. per ton, although a short time previously it did not exceed 5*s*. 6*d*. per ton. For many years prices did not exceed 6*s*. per ton for manufacturing coal; in 1871 and 1872 however the same variety rose to 20*s*. and even 25*s*. per ton, and even at this price manufacturers were greatly inconvenienced, being unable to secure a supply; indeed, it was not uncommon at the period referred to, to use the best house coal instead of ordinary steam coal for manufacturing purposes.

The following table shows generally the prices ruling in the Manchester district, at the pit's mouth, in the year 1870:—*

COLLIERIES.

Altham (coal), 6*s*.
Bank Hey (coal), 5*s*. 8*d*.
Birtle Dean (coal), 7*s*. 6*d*.
Breightmet (house coal), 7*s*. 6*d*.; (engine coal), 4*s*. 9*d*.

* Coal Commission Report, vol. iii., Appendix, p. 213, prices at the pit's mouth.

COLLIERIES.

Broadfield (coal), 5*s.* 9*d.*, 8*s.*, 12*s.* 6*d.*
Combermere (coal), 4*s.* 6*d.*
Great Lever (best coal), 10*s.*; mixed, 8*s.*; steam, 5*s.*
Lower Moor (best coal), 10*s.* 6*d.*; small, 6*s.*
Redsham, 5*s.* to 8*s.* 4*d.*
Stand Hill (coal), 5*s.* 3*d.*
Wharton, best, 6*s* 8*d.*; riddled, 5*s.* 5*d.*; burgie, 3*s.* 9*d.*; slack, 2*s.* 6*d.*
Tyldesly, 8*s.* 9*d.* summer; 9*s.* 7*d.* winter.

In the Saint Helen's district prices averaged from 4*s.* 6*d.* to 5*s.* 6*d.* per ton. And in the Wigan district prices varied, best coals from 5*s.* 9*d.* to 7*s.* 6*d.* per ton; common from 4*s.* 8*d.* to 5*s.* and slack from 2*s.* 4*d.* to 3*s.* per ton. From the evidence of Mr. Alfred Hewlett, the Managing Director of the Wigan Coal and Iron Company,* in whose collieries some 10,000 persons are employed, producing nearly 2,000,000 tons of coal per annum, some very important facts are gathered. In referring to the condition of the coal trade, he says,—"From 1867 to 1870 the coal trade of the district was in a very depressed state, large stocks were accumulating on the pit banks and on the wharves; prices were very low. Competition for a market consequently ran high, and the pits were obliged to be put on very short time, in many cases half-time, owing to the absence of demand. An improvement sprung up towards the end of 1870, but still the standard of production of 1867 has not since been reached." Again, referring to the price realised for coal since 1867, he observes:—"Taking 1867 as the datum, in 1868 the average price of coal was 6½ per cent. less than in 1867; in 1869 it was 9½ per cent. less than in 1867; in 1870 it was also 9½ per cent. less; in 1871 it was 8 per cent. less; in 1872 it was 34 per cent. more than in 1867; and for the first quarter of 1873 it was 82½ per cent. higher than in 1867; the above represent prices at the pit's mouth."

About this time (April, 1873), the average earnings of the colliers, working from eight to eight and a half days in the fortnight, were:—in the Cannel Mine, one man earned 13*s.* 1*d.*; another, 10*s.* 4*d.*; another, 11*s.* 2½*d.*; another, 15*s.* 0½*d.*; another, 18*s.* 4½*d.* In another seam, at the same time, one man earned 9*s.* 3*d.*; another, 13*s.* 4½*d.*; another, 15*s.*; another, 12*s.* 1*d.*; another, 11*s.* 9*d.* The general effect of the operation of "The Coal Mines Regulation Act, 1872," being to increase the cost of

* Select Committee on Coal Report, 1873, pp. 72—74.

production from 1*s.* 4*d.* to 1*s.* 8*d.* per ton, due to the restrictions as to employment of boys underground, the provision for weighing, and the decrease in the hours of labour.

In the years 1878, 1879, and 1880 the average, with the highest and lowest prices of coal and slack at the pit's mouth, was as under:—

Year.	COAL.			SLACK.		
	Average.	Highest.	Lowest.	Average.	Highest.	Lowest.
	s. *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
1878	9 0	13 0	7 0	5 0	6 8	3 0
1879	8 6	20* 0	6 0	4 4	5 10	2 0
1880	8 9	18* 9	6 8	4 6	5 6	2 6

In December, 1880, the best qualities of Lancashire house-coal were to be bought at from 8*s.* 6*d.* to 9*s.* 6*d.* per ton; seconds from 6*s.* 6*d.* to 7*s.*; common round coal, 5*s.* 6*d.* to 6*s.* 6*d.*; burgie, 4*s.* to 4*s.* 3*d.*, and good slack, 4*s.* to 4*s.* 6*d.* per ton at the pit's mouth. Now, in March, 1881, best coal is quoted at 10*s.* to 10*s.* 6*d.*; seconds, 8*s.* to 8*s.* 6*d.*; common coal, 6*s.* 6*d.* to 7*s.*; burgie, 5*s.* to 5*s.* 10*d.*, and slack, 4*s.* to 4*s.* 6*d.* per ton; these increased prices being due to the recent strike extending through the Lancashire coal-field, involving a complete stoppage of work on the part of, at least, 50,000 men and boys for nearly three weeks, including the colliers and day men employed about the pits. In the Manchester and Bolton districts, from 13,000 to 14,000 men ceased work, during the period of the strike extending over a period of nearly six weeks, and in the West Lancashire district, at one period 36,000 to 37,000 men were out during the period of the dispute, extending to nearly two months.

Resources of Coal-field and Probable Duration.—The total area of the Lancashire coal-field amounts to 5,862,390 statute-foot acres of coal wrought and unwrought, excluding all seams that are not of workable thickness. Of this acreage the portion already wrought amounts to 597,604 statute-foot acres, leaving 5,264,786 statute foot acres for future supplies. From this area, however, necessary deductions are made for faults, supports,

* Cannel Coal.

barriers, &c., leaving unwrought and likely to be clear for working, 3,883,372 statute-foot acres. In computing the available quantity of coal in this acreage (5,436 millions of tons), one-fourteenth has been allowed for unavoidable loss, waste in working, the actual estimated quantity of coal obtained from each foot-acre being taken at 1,400 tons of 2,240 lbs. each.

Taking the production of Lancashire (1870), when the output was 13,810,600 tons, sufficient coal remains from that date for a period of 393 years. The total production during the past ten years amounts to 165,313,301 tons; this, deducted from original estimate, leaves 5,270,686,699 tons; and taking 16,513,330 tons, the average output of the ten years, there would be sufficient to last for 317 years; while at the rate of consumption in 1879, when the production was 18,612,345 tons, the resources of the coal-field would be exhausted in 283 years, and as production will increase, at an earlier period.

From the reports of H.M. Inspectors of Mines for the year 1880, it appears the total production of the Lancashire coal-field exceeded that of any previous year, the output amounting to 19,120,294 tons; at this rate of production the exhaustion of the Lancashire coal deposits would take place about 275 years hence.

CHAPTER V.

CHESHIRE COAL-FIELD.

Description of Coal-field and Principal Seams—Analyses, Production, and Distribution of Coal—Population Employed in Coal Mining—Resources of Coal-field and probable Duration.

The Cheshire Coal-field.—This coal tract lying to the south of the River Mersey has its most northern part situated near Stockport, the central portion lies east of Poynton, and the southern termination of the coal-field is near Macclesfield. The annexed section shows the order of occurrence of the coal series in the neighbourhood of Bredbury, near Stockport, where the following seams have been worked at the Bredbury collieries.*

COAL-SERIES OF BREDBURY, CHESHIRE.

	Ft.	In.
Black Mine (coal)	4	0
Strata	24	0
Coal	0	10
Strata	27	0
Coal and Dirt	2	0
Strata	105	0
Stone Mine { Coal 1 3 / Stone 1 0 / Coal 1 0 }	3	3
Strata	45	0
Cannel Mine (common coal here)	1	4
Strata	96	0
Peacock or *King William Coal*	2	6
Strata	75	0
Coal	0	10
Strata	76	0
Coal	1	10
Strata	45	0
Silver Mine (good coal)	3	2

Below these occur the following coals not worked at Bredbury:—

	Ft.	In.
Water Mine { Coal 3 0 / Shale 1 0 / Coal 1 0 }	5	0
Rosemary Mine / Upper Woodley Mine / Lower Woodley Mine } Thickness uncertain.		

* "Explanation Horizontal Section of Sheet 65." Geol. Survey of Great Britain.

Professor Hull, referring to this coal-field, says it is bounded along the west by Triassic and Permian rocks, which are brought in along the line of the "Red Rock fault of Cheshire," and that several valuable seams of coal occur, including the "Mill Mine" 4½ feet thick; the "Sheepwash Mine;" the "Great Mine;" the "Silver Mine;" the "New Mine;" and the "Redacre Mine," which represents the Arley or Royley Mine.*

Analysis of Cheshire Coal.—The character of the Cheshire coal will be understood from the results of the annexed analysis showing the composition of coke made from coal raised from the Dukinfield Colliery; the analysis is given by Dr. Percy in his Metallurgy, and was made by Mr. C. Tookey in the laboratory of the Royal School of Mines:—

Carbon	85·84
Hydrogen	0·52
Oxygen and Nitrogen	1·38
Sulphur	0·86
Ash	11·40
	100·00†

Coke, Dr. Percy remarks, "consists essentially of carbon and the fixed inorganic matter of the coal from which it has been derived, but contains, also, hydrogen, nitrogen, and oxygen with sulphur in the state of sulphide of iron. Half the sulphur in the original coal, or thereabouts, is found in the coke made from it; the bisulphide of iron in the coal being converted into protosulphide by the burning off of one equivalent of the sulphur, and the production of sulphurous acid."

The Cannel coal, raised by the Dukinfield Coal and Cannel Company from their Dunkirk Colliery, where the seam averages 2 ft. 6 in. in thickness, has been examined by Mr. Robert J. Toothill, analytical chemist of Manchester, with the following results:—

TABULATED.

Yield of gas per ton	9962 cubic feet.
Temperature 60° Fahr.	——
Illuminating power	= 25·5 candles.
Coke (hot)	13 cwts. 3 qrs.
Coke (slacked) ready for sale	15 cwts. 3 qrs. 16 lbs.
Water	15 gallons.
Specific gravity 4°	at 60° Fahr.
Tar	15 gallons.
Specific gravity 28°	at 60° Fahr.
Coke	good.

* "Geology of Stockport, &c." Mem. Geol. Survey, p. 29.
† "Percy's Metallurgy," Fuel, p. 417.

The Cannel nuts raised by the same company yielded per ton 9,700 cubic feet of purified gas, at a temperature of 60 degrs. Fahr. illuminating power = 18·5 candles.

Coke (hot)	13 cwts. 0 qrs. 12 lbs.
Coke (slacked) ready for sale . . .	16 cwts. 0 qrs. 24 lbs.
Water, 9 galls. 1 qrt. . . .	Specific gravity 5¼° at 60° Fahr.
Tar, 12 galls. 2 qrts. . . .	,, ,, 26½° at 60° Fahr.

The mine from which the above Dunkirk cannel, and cannel nuts, are obtained is termed the Cannel Mine. Its depth at the above company's Astley Deep Pit from the surface is 736 yards, it being fifty yards below the well-known Black Mine of the district to which the shafts of the company are sunk. It is got at by tunnels from the last-named mine.

Production and Distribution of Coal.—The Cheshire collieries, although yielding a notable quantity of coal, are not accredited with returns of production prior to the year 1854. It is probable that the returns of the Lancashire coal-field at an early period included the Cheshire coal. In the year above-named, 32 collieries in operation gave an output of 786,500 tons of coal, of which quantity the London and North-Western Railway carried 157,505 tons, to the great industrial centres of Manchester, Macclesfield, Stockport, &c. The output of the coal-field and the number of the collieries in recent years are as under :—

Year.	Number of Collieries.	Coal Raised.	Year.	Number of Collieries.	Coal Raised.
		Tons.			Tons.
1855	32	755,500	1868	29*	937,500
1856	32	754,327	1869	28*	957,150
1857	31	750,500	1870	29	929,150
1858	35	695,450	1871	29	975,000
1859	35	700,000	1872	31	†
1860	35	750,500	1873	31	1,150,500
1861	39	765,570	1874	36	615,105
1862	39	787,750	1875	37	658,945
1863	39	822,750	1876	39	584,580
1864	38	821,700	1877	36	645,500
1865	39	850,000	1878	33	616,575
1866	38	893,000	1879	26	720,350
1867	39	935,000	1880	30	681,000‡

* Several small collieries chiefly near Macclesfield ceased to work in those years.

† Included in North Staffordshire. Production not less than 1,000,000 tons.

‡ Report H.M. Inspectors of Mines.

In Cheshire the chief of the great railway lines is the London and North-Western, passing by the south, to Stafford, Crewe and Warrington to the north. From Crewe branches pass to Stockport and Manchester on the east, and to Chester and Birkenhead on the west. At Crewe, it may be mentioned, is situated the great engine factory and steel works of the London and North-Western Railway, which line carried coals from Cheshire as follows in each of the years named:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1854	157,595	1864	110,891
1855	100,000	1865	123,588
1859	160,000	1866	135,092
1860	150,000	1868	148,236

These quantities include coal carried by the company and passed over to other lines, which, in the returns of later years, are separately distinguished as under:—

Year.	Stations on London and North-Western Line.	Stations on Other Lines.	Total Carried.
	Tons.	Tons.	Tons.
1869	121,202	2,964	123,896
1870	103,885	599	104,484
1871	140,452	773	141,225
1872	132,775	239	133,014
1873	100,354	7,226	107,580
1874	117,624	1,390	119,014
1875	135,304	619	135,923
1876	147,741	685	148,426
1877	157,080	271	157,351
1878	155,062	310	155,372
1879	168,761	338	169,099
1880	179,108	5,707	184,815

It is not an easy matter to determine the quantities of coal exported from this coal-field; much of it being shipped from ports on the Mersey, and this is included in the returns of the port of Liverpool. The shipments from the port of Chester to foreign parts show but little variation; but the shipments coastwise show a great diminution, which is explained by the large quantities carried by railway. The movements of coal,

coastwise, and to foreign countries, were as follows in each of the years named :—

Year.	Coastwise.	Foreign.	Total.
	Tons.	Tons.	Tons.
1851	101,044	949	101,993
1854	91,469	360	91,829
1857	73,850	107	73,957
1860	56,838	200	58,838
1863	61,866	1,431	63,297
1866	59,818	600	60,418
1869	73,813	2,797	73,610
1872	85,986	7,098	93,084
1873	109,023	10,679	119,702
1874	90,049	7,959	98,008
1875	96,842	8,823	105,665
1876	67,646	6,137	73,773
1877	83,512	4,822	88,334
1878	68,826	4,602	73,428
1879	53,455	5,855	64,310
1880	64,349	7,679	72,028

Population employed in Coal-mining in Cheshire.—In the year 1854, the number of persons engaged in coal-mining was 2,618, the coal raised amounting to 786,500 tons. Twenty years later the numbers were 2866, of whom 2,253 were engaged underground, and 613 above ground, the output of coal being 614,956 tons. Since the year 1874 the numbers employed and coal raised have been as under :—*

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	2,253	613	2,866	614,956	227
1875	2,059	685	2,744	688,865	251
1876	1,939	699	2,638	594,300	225
1877	1,814	587	2,401	629,000	261
1878	1,875	584	2,459	617,000	251
1879	1,835	549	2,384	723,200	303
1880	1,961	530	2,491	681,000	273

A comparison of the average output of each collier between the years 1874 and 1879 exhibits steady working, amounting to an increase of upwards of 30 per cent., the average per man

* Reports of H.M. Inspectors of Mines.

increasing from 227 to 303 tons; a falling off appears in 1880, the average per man not exceeding 273 tons. In the year 1879 the ages of those employed are thus distinguished:—

All Ages.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
From 12 to 13 .	20	...	20
„ 10 to 13 . .	...	10	10
„ 13 to 16 .	141	38	179
Above 16 . . .	1,674	501	2,175
Total . .	1,835	549	2,384

Resources of Coal-Field and Probable Duration.—The total area of the Cheshire coal-field,* wrought and unwrought, to a depth not exceeding 4,000 feet, amounts to 236,797 statute acres one foot thick. Of this area 232,029 acres occur at a depth not exceeding 3,000 feet; and 4,768 acres at a depth between 3,000 and 4,000 feet.

The portion already wrought of the above 236,797 statute-foot acres in 1870 was 40,000 acres, leaving at that date 196,797 acres for future use. From this area large deductions are made, for faults, supports, barriers, &c., amounting to 54,149 acres, leaving portion unwrought and likely to be clear for working, 142,648 acres of one foot in thickness, equivalent to 200,000,000 tons of coal.

In the above computation the Commissioner allows one-fourteenth for unavoidable loss and waste in working, or 1,400 tons per statute-foot acre.

Considering the production of this coal-field in 1870, amounting to 929,150 tons, supplies are yet available for 215 years from that date. During the ten years ending 1879 the total coal raised amounted to 7,895,705 tons; this deducted, leaves as under:—

	TONS.
Original estimate, 1870	200,000,000
Deduct ten years ending 1879	7,895,705
Total available . . .	192,104,295

A reference to the returns of production shows that from 1870 to 1873 the maximum was attained, amounting to 1,150,500 tons.

* Report Royal Coal Commissioners. Mr. Joseph Dickinson, vol. i., p. 18.

Since 1873 a falling off has taken place, the output in 1879 being 720,350 tons. It therefore appears that the output of 1879 would afford supplies for 266 years, while the average output of the ten years, namely, 789,570 tons, would give 243 years, and the output of 1873, the year of greatest production, but 167 years for the exhaustion of the coal to a depth of 4,000 feet.

The returns for the year 1880 exhibit a decrease compared with the previous year, the quantity not exceeding 681,000 tons.

Coal used in Manufacture.—An important industry of Cheshire, namely, salt manufacture, employs considerable quantities of coal, of which it appears 10 cwts. are used in the manufacture of each ton of salt.

CHAPTER VI.

DERBYSHIRE COAL-FIELD.

Description of Coal-field and Succession of Strata at Kilburne and Shipley Collieries—Analyses, Production, and Distribution of Coal—Prices of Coal—Population Employed in Coal and Ironstone Mining—(Resources and Duration included in the Great Coal-field of York, Derby, and Notts).

Derbyshire Coal-field.—This coal-field, with that of Nottinghamshire, includes the southern extension of the Yorkshire coal-field. The succession of strata in Derbyshire is well illustrated by the following section, showing the coal series in descending order from the base of the magnesian limestone. The section is taken across the coal-field, from Wingfield to the escarpment of the magnesian limestone, a distance of nearly seven miles:—*

SUCCESSION OF STRATA.

		Ft.	In.
Sandstones and shales		350	0
Coal		2	10
Strata		107	0
Coal		2	1
Strata		220	0
Barnsley *Top Hard Coal*	5 ft. 10 in. to	7	0
Strata, Brown Rake and Black Rake ironstones		470	0
Soft Coal (generally two seams with partings)		6	0
Strata		120	0
Lower Hard Coal	3 ft. 0 in. to	4	0
Strata		200	0
Furnace Coal	2 ft. 6 in. to	4	0
Strata with nodular ironstone		140	0
Silkstone *Clod or Black Shale Coal*	5 ft. 0 in. to	7	0
Strata		385	0
Kilburne Coal	4 ft. 0 in. to	5	0
Strata with Honeycrop Ironstone		200	0
Wingfield Flagstones		350	0
Black Shales		300	0
Flagstones and shales		200	0
Coal with a floor of Ganister		1	0
Flagstones and shales		125	0
Ganister Coal (with a floor of Ganister)		2	0
Flagstones and shales		600	0
Millstone grit			

* "Geological Survey of England and Wales." Explanation of Horizontal Sections. Sheet 60. 1869.

The total thickness of measures in the above section down to the limestone grit, is 3,808 feet, with about 40 feet of workable coal, the principal seams of which are the "Top Hard" and the "Lower Hard," the "Black Shale" and Kilburne Coal. This last-named coal is the lowest workable seam above the Ganister coal, and the following is the section of the strata above and beneath the coal at Kilburne Colliery:—

SECTION AT KILBURNE COLLIERY.

		Ft.	In.
Shales		29	7
	Coal	2	1
Sandstones and shales		65	4
	Coal	1	4
Shales		58	0
	Coal	1	8
Sandstones and shales		95	1
	Coal and sloom (soft clay)	2	6
Sandstones and shales		111	7
Kilburne Coal	Coal . 3 ft. 10 in.; Sloom . 0 ,, 2 ,,; Coal . 1 ,, 2 ,,	5	2
Clunch (soft clay) full of "dogtooth" ironstone		2	7
Ironstone measures	*Ironstone*	0	2
	Dark bind	2	0
	Ironstone	0	2
	Dark shaley bind	1	10
	Ironstone	0	3
	Shaley bind	3	6
	Ironstone	0	2
	Shaley bind	2	2
	Ironstone	0	3
	Shaley bind	2	2

From the outcrop of the Kilburne coal the dip is north till the centre of Shipley Basin is reached, where the beds are flat, and comprehend all the coal-series from the Top Hard seam inclusive.

The following are the names of the coals at Shipley Colliery:—

	Ft.	In.
Soft Coal	1	6
,, and smut	2	10
Soft Coal	2	0
Light-coloured clay	0	6
Soft Coal	1	10
Light-coloured clod	0	4
Soft Coal	1	2
Top Hard Coal	6	2
Old Greaves Coal	3	0
Soft Coal	1	6
,,	0	9

	Ft.	In.
Waterloo Coal	3	8
Soft Coal	1	6
,,	2	0
,,	1	4
Cannel	2	0
Soft Coal	1	4
Coal and shale	3	0
Bright Soft Coal	4	3
Black Clod (Clay)	4	9
Soft Coal	0	9
Bottom Hard Coal	5	6

East and north of Shipley Colliery the beds rise and the Top Hard coal crops out.

Analyses of Derbyshire Coal.—Of the various coal seams worked in the Derbyshire area of the Midland coal-field, a few of the more important will show the general character and purposes to which they are suited. The *Top Hard Coal,* for example, worked at Staveley Colliery, four miles N.E. of Chesterfield, is a seam of great regularity in its occurrence, with an average thickness of six feet. The coal is described as a "strong splint which may be exposed for years to atmospheric influence without change or waste," and is extensively used in Derbyshire and Yorkshire in the various stages of iron manufacture. In structure these coals somewhat resemble silicified wood, but seem to have two distinct planes of cleavage at right angles to each other, which give the fragments the form of long four-sided prisms, which, when broken, give rise to splinters of the same shape. The coal is usually found to contain quantities of iron pyrites in the lines of cleavage, and when tried under the boiler, it is found to light easily and burn freely, yielding much smoke, and it was observed that when a fresh charge is thrown on the fire, a crackling is heard occasioned by the decrepitation of the coals.

The "*Loscoe Hard and Soft Coals*" are two seams worked at Loscoe Colliery, situated on the borders of Nottinghamshire, ten miles from Derby, and twelve from Nottingham. The Hard Coal seam is 32 inches in thickness, and is worked at a depth of 130 yards from the surface, whilst the Soft Coal Seam is about 12 inches thick, and is obtained from a depth of 112 yards. These coals differ greatly in their qualities, the "soft" coal being considered a good household and gas coal, whilst the "hard" is chiefly recommended for steam purposes. The Loscoe soft

coal is described as bright, with a splintry fracture containing much shale and iron pyrites; the harder variety is duller in its general appearance, and contains thin layers of very bright coal, together with iron pyrites and white shale.

The "*Langley Hard Coal.*" This coal is extracted from the Lower Hard coal seam of Derbyshire and Nottinghamshire; at Heanor in the former county, the seam is three feet in thickness, and is raised at a depth of seventy yards from the surface. This coal finds a ready market in the neighbouring counties of Notts, Lincoln, Leicester, Rutland, and Northampton. The composition of the above-named coals appears in the annexed analyses, to which is added the specific gravity and the yield of coke:—*

Constituents.	Staveley "Top Hard."	Loscoe Soft Coal.	Langley Hard Coal.
Carbon	79·85	77·49	77.97
Hydrogen	4·84	4·86	5·58
Nitrogen	1·23	1·64	0·80
Sulphur	0·72	1·30	1·14
Oxygen	10·96	12·41	9·86
Ash	2·40	2·30	4·65
	100.00	100·00	100·00
Specific gravity	1·27	1·285	1·264
Coke per cent.	57·86	52·80	54·90

Dr. Percy † gives the following analyses of Derbyshire coals, the first consisting of the average of a mixture of thirteen different seams worked in the Renishaw Colliery, and the second of coal raised at the Monkwood Colliery also situated near Chesterfield:—

RESULTS TABULATED.

Constituents.	Renishaw.	Monkwood.
Carbon	77·12	83·18
Hydrogen	5·05	4·76
Oxygen and Nitrogen	8·08	6·79
Sulphur	1·61	1·42
Ash	5·82	1·70
Water	2·32	2·15
	100·00	100·00

* Appendix, Third Report. Coal Suited to the Steam Navy, pp. 29, 55.

† "Metallurgy," Fuel, p. 32. The Monkwood coal yielding of coke 65·75 per cent.

Production of Coal and Distribution.—Towards the close of the last century, although it was generally known that coal was raised from the many collieries of Derbyshire in considerable quantities, no exact record is met with. It was certainly considerable, besides which a large quantity was conveyed by the Erewash Canal to Leicestershire for consumption in that county. Pilkington,* writing about the year 1789, describes the coal raised in Derbyshire as of two varieties or general divisions, "hard" and "soft." The soft coal, he adds, "which lies much nearer to the surface, is found in most of those shafts in which the other sort is met with. It is generally shattering and sulphureous. It is much used for burning limestone and the manufacture of iron goods. A large quantity is also converted into coak." The "hard" coal, which is more useful and valuable, is more varied in its nature and properties.

The earliest return of production met with appears in Farey,† where it is recorded that for the twelve months ending June, 1808, 8,280 boat-loads of coals passed on the Erewash, Cromford, and Nottingham canals, on their way towards the places of consumption; these contained—

	TONS.
Hard Coals	205,006
Soft Coals	37,289
Cobbles	27,161
Coke	24,384 qrs.

The value of which amounted altogether to £122,838.

Not again until the year 1816 does any reliable data appear showing the quantity of coal raised in Derbyshire, for that year; however, it is gathered from the report of a deputation from the Wear, sent to inquire into the quantities of coals conveyed by railway and canal in different parts of the kingdom, that 355,554 chaldrons were thus distributed, and, assuming these as Newcastle chaldrons of 53 cwts. each, a total appears of 942,000 tons; the total estimated production of the kingdom the same year being set down at 27,020,115 tons. Again, in the year 1854, inquiries over the several districts gave the following as the quantities of coal raised:—‡

* James Pilkington. "View of Derbyshire." Derby, 1789.

† "View of Derbyshire." John Farey, 1811, p. 185.

‡ "Mineral Statistics of the United Kingdom."

DISTRICTS.	TONS.
Chesterfield	1,098,696
Alfreton	650,000
Ripley	145,000
Glossop	70,000
Ilkeston	263,000
Burton-on-Trent	180,000
Total	2,406,696

Of the collieries in the Erewash Valley district there was sold and conveyed to distant places during the year 1854 :—

HOW DISTRIBUTED.	TONS.
By canal or water sale	323,129
By railway sale	599,247
Total	922,376

The London and North-Western Railway carried and distributed 328,505 tons, and large quantities were also carried from the district by the Midland Railway.

In later years the number of collieries and production of coal in Derbyshire were as given in the annexed table :—

Year.	Number of Collieries.	Coal raised.	Year.	Number of Collieries.	Coal raised.
		Tons.			Tons.
1855	171	2,256,000	1868	142	4,957,879
1856	176	2,298,325	1869	140	5,460,090
1857	171	2,612,372	1870	137	5,102,265
1858	161	*3,960,750	1871	130	5,360,000
1859	153	*4,250,000	1872	156	†
1860	153	*4,940,000	1873	156	†
1861	158	*5,116,319	1874	243	7,150,570
1862	155	4,534,800	1875	255	7,091,325
1863	155	4,550,750	1876	261	7,025,350
1864	154	4,470,750	1877	234	6,975,550
1865	154	4,595,750	1878	237	7,190,000
1866	150	4,750,520	1879	234	7,450,370
1867	150	4,550,550	1880	234	7,903,834

Examining the above returns of production, it will be seen that in the year 1875 the output had increased threefold compared with the year 1855, since which date the production has been well maintained, exhibiting but little variation; in 1879 a marked increase appears over the previous year, amounting to upwards of 250,000 tons, or nearly 4 per cent.

* Including the produce of Nottinghamshire.

† Included in the returns of Notts, Leicester, and Warwick.

The steady development of the Derbyshire collieries comes out clearly in the returns of distribution. In the year 1855 the Midland Railway carried out of Derbyshire 415,357 tons, which was distributed in Rugby and other places on the London and North-Western Railway. The quantities carried by the Midland Railway and the London and North-Western Railway for 1860 and previous years were as follows :—

Year.	MIDLAND RAILWAY.		LONDON AND NORTH-WESTERN.
	North Derby.	Erewash Valley.	
	Tons.	Tons.	Tons.
1856	557,825	867,288	...
1857	545,312	916,317	...
1858	595,380	972,715	...
1859	...	968,026	675,000
1860	537,890	...	...

Before giving the returns of distribution for the past twenty years, it will be desirable to call attention to an early return of the sales of coal by canal from the collieries in the Erewash Valley, dating from the year 1803, when the sales amounted to 254,268 tons, increased to 427,670 tons in the year 1848.* The figures below are from the return referred to :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1803	254,268	1830	253,498
1806	267,204	1833	316,187
1809	321,056	1836	377,103
1812	279,280	1839	377,606
1815	298,482	1842	410,495
1818	236,372	1845	334,159
1821	331,840	1846	385,695
1824	318,624	1847	475,779
1827	288,678	1848	427,670

From the annual statements of accounts published by the "Association of Coal Owners of the Erewash Valley, Leicestershire, and North and South Derbyshire," very complete returns are obtained, showing the sales of coal by railway and canal. The above-named association was dissolved in 1877 and a new

* For details of each year's sale, see Coal Commission Report, vol. iii., Appendix, p. 16.

one founded.* The returns for a few years will show the condition of the coal industries of Derbyshire under the auspices of the Association; the figures are as follows:—

Year.	Erewash Valley.	North Derbyshire.	South Derbyshire.
	Tons.	Tons.	Tons.
1860	1,926,167	537,890	...
1862	1,329,766	351,208	...
1864	1,742,543	483,132	...
1865	1,739,979	466,448	...
1866	1,843,397	450,515	...
1867	1,825,798	503,137	128,381
1868	1,634,624	517,384	165,210
1869	1,781,964	598,086	121,392
1870	1,924,718	628,153	268,477
1871	1,949,428	840,291	331,790
1872	2,091,377	1,041,183	374,846
1873	2,046,017	1,212,440	344,071
1874	2,026,013	878,246	463,832
1875	1,917,759	765,835	410,231
1876	1,744,511	554,509	366,554

Beyond these returns, the collieries in Nottinghamshire and Leicestershire, also in the Association, sent away coals in lesser quantities, bringing up the total sales of the Association in each of the same years to the following figures:—

LEICESTERSHIRE AND NORTH DERBYSHIRE ASSOCIATION SALES.

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1857	1,837,920	1867	3,054,303
1858	1,925,584	1868	2,853,512
1859	2,019,546	1869	3,282,625
1860	3,115,883	1870	3,440,374
1861	2,473,732	1871	3,784,212
1862	2,267,998	1872	4,227,381
1863	2,492,893	1873	4,260,704
1864	2,870,148	1874	3,924,793
1865	2,818,154	1875	3,482,861
1866	2,952,788	1876	3,013,925

In the above returns it should be remembered that the quantities do not include the local or land sales, nor coals used for iron-making purposes, but only railway and canal sales. The extent of these sales may be gathered from the annexed details for the years given:—

* "The Derbyshire, Leicestershire, and Nottinghamshire Coal Owners Association," from which no returns are published, but issued to members only.

Districts.	1860.	1870.	1876.
	Tons.	Tons.	Tons.
Erewash Valley	1,926,167	1,924,718	1,744,511
Leicestershire	651,826	462,427	213,574
North Derbyshire . .	537,890	628,153	554,509
South Derbyshire . . .	...	268,477	366,554
Nottinghamshire . . .	...	156,599	134,777
Totals	3,115,883	3,440,374	3,013,925

Previous to the year 1848, the chief means of distributing the coals of those collieries situated in the Erewash Valley was by the canal bearing the same name; in 1849, however, for the first time, returns are available, showing the quantity carried by railway. These latter show a greatly increased traffic till the year 1875, when a falling off appears, and again in 1876, when the last return was published. The details given below show the sales by railway and canal of the "Associated Collieries of the Erewash Valley District" from 1849 to 1876:—

Year.	Canal.	Railway.	Total.
	Tons.	Tons.	Tons.
1849	386,955	43,820	430,775
1851	334,922	251,079	586,001
1853	320,408	497,961	818,369
1855	223,893	753,277	977,170
1857	227,704	776,948	1,004,652
1859	208,905	968,026	1,176,931
1861	218,421	1,282,669	1,501,090
1863	223,972	1,347,944	1,571,916
1865	210,440	1,649,542	1,859,982
1867	196,579	1,749,225	1,945,804
1869	192,902	1,709,061	1,901,963
1870	148,342	1,776,114	1,924,456
1871	148,926	1,800,502	1,949,428
1872	146,610	1,944,767	2,091,377
1873	124,490	1,921,527	2,046,017
1874	106,163	1,919,853	2,026,017
1875	105,479	1,730,636	1,836,115
1876	102,430	1,502,378	1,604,808

The great increase in the movement of coal since the introduction of railways is shown in the above returns. In 1849, the first return of coal carried from the collieries in the Erewash Valley district, gives 43,820 tons, increased to 968,026 tons in 1859, and 1,944,767 tons in 1872, since which a falling off appears. On the other hand the coal sales by canal exhibit a falling off

from 386,955 tons in 1849, to 102,430 tons in 1876, when these returns were discontinued.

The foregoing statements of distribution refer to the produce of those collieries in the districts named; for complete returns of the distribution of coal by railway, the statements annually furnished by the several railway companies, and published in the "Mineral Statistics," afford the desired information. The most important of these returns are those of the Midland Railway, whose system has in a greater degree than any other, contributed to the distribution of the vast deposits of coal of the Midland coal-fields of Yorkshire, Derbyshire, Nottinghamshire, Leicestershire, and Warwickshire.

In the following table is given the distribution of coal, the output of the Derbyshire collieries, by the Midland, London and North-Western, Great Northern, and Manchester, Sheffield, and Lincolnshire Railways, since the year 1855:—

Year.	Midland Railway.	London and North-Western Railway.	Great Northern Railway.	Manchester, Sheffield and Lincolnshire Railway.
	Tons.	Tons.	Tons.	Tons.
1855	*415,357	328,505	...	...
1856	1,425,113	...	...	...
1857	1,461,629	...	...	...
1858	1,568,095	...	...	...
1859	1,743,769	675,000	...	...
1860	†2,230,275	...	159,412	132,641
1861	†2,370,817	...	232,696	122,656
1862	†2,283,406	‡766,899	356,540	...
1863	2,514,128	‡907,646	...	...
1864	3,013,730	20,379	...	...
1865	2,577,690	...	...	...
1866	3,135,855	24,982	526,072	...
1867	3,555,745	32,378	620,409	219,587
1868	2,350,393	53,824	585,113	229,867
1869	3,617,082	42,129	558,735	293,456
1870	4,079,447	66,217	573,261	...
1871	4,595,527	34,355	375,439	...
1872	4,875,044	29,201	357,580	137,325
1873	5,197,550	25,463	441,226	227,622
1874	5,252,740	30,140	416,202	331,285
1875	5,488,592	33,485	499,044	342,312
1876	5,022,347	33,214	619,494	239,464
1877	5,155,152	40,577	735,120	293,885
1878	5,173,115	40,203	824,337	306,380
1879	5,689,527	38,190	955,468	387,275
1880	5,603,872	27,632	896,636	408,836

* Not including collieries in Erewash Valley.

† Including Nottinghamshire collieries. ‡ Midland Coal-field.

Prices of Coal in Derbyshire.—In 1860 the average cost of coal loaded into carts or trucks at the pit's mouth varied from 5*s.* to 5*s.* 6*d.* per ton. The selling price of best coals being about 9*s.* per ton, and ordinary coals 6*s.* 6*d.*, cartage in the district increasing the price by about one shilling per ton per mile, while, as regards railway carriage, the cost for long distances, exclusive of waggons, was ½*d.* per ton per mile.

Advancing to the year 1870, it appears from the Report of the Coal Commission * that the average prices of coals in the Chesterfield district were as follows:—

		s.	*d.*
Brimington		6	6
Monkwood	6*s.* 0*d.* *to*	9	0
Renishaw		6	8
Woodhouse Hard		7	6
,, *Soft*		7	1
,, *Small*		4	7

And in the Alfreton district:—

	s.	*d.*		*s.*	*d.*
Coates Park, Screened	5	0	to	5	6
,, Cobbles	6	0	,,	7	0
,, Brights	8	0	,,	8	6
Shirland, Round	5	6	,,	8	0
Swanwick, average	5	0	,,	12	0

In recent years the average price per ton at the pit's mouth of coal and slack was as follows:—

Year.		Average. *s.* *d.*	Highest. *s.* *d.*	Lowest. *s.* *d.*
1878	Coal	8 4	11 0	6 6
	Slack	3 6	5 3	2 6
1879	Coal	7 3	10 6	6 0
	Slack	4 3	5 9	2 0
1880	Coal	7 6	10 0	6 1
	Slack	4 4	5 0	2 4

Showing a falling off in the price of coals and an increase in that of slack in 1880 compared with the previous years.

Population employed in Coal and Ironstone Mining.—The total number of male persons employed in coal mining in Derbyshire in 1854 was 5,434, and in ironstone mining 1,428, giving a

* Vol. iii., Appendix, p. 212.

total of 6,862; the total quantity of coal raised in the same year was 2,406,696 tons.

The first return distinguishing the number of persons employed underground and above ground in Derbyshire in coal mines appeared for the year 1873,* when 22,173 persons were engaged underground, and 5,950 above ground, giving an aggregate of 28,123 persons employed, the output of coal amounting to 6,977,587 tons. In the following table the total numbers appear for each year since, with the output of coal and average produce per man:—

Year.	Persons Employed.		Total Employed.	Coal raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	22,173	5,950	28,123	6,977,587	249
1874	24,019	6,461	30,480	7,152,944	234
1875	23,683	6,414	30,097	7,190,921	238
1876	23,078	6,508	29,586	6,959,101	242
1877	21,937	6,148	28,085	7,054,091	251
1878	21,190	5,785	26,975	7,289,380	270
1879	21,713	6,146	27,859	7,561,235	271
1880	21,183	6,073	27,256	7,903,834	290

The average produce per man shows increased efficiency, to the amount of 41 tons in eight years, equal to nearly 16 per cent.

The ages of those employed in the year 1879 above and below ground were as under:—

Ages.	Under Ground.	Above Ground.
From 10 to 12	4	...
,, 10 to 13	...	35
,, 12 to 13	112	...
,, 13 to 16	2,201	539
Above 16	19,396	5,572
Total	21,713	6,146

The resources and probable duration of the Derbyshire coal-field are considered in the account of the Yorkshire coal-field.

* See Reports of H.M. Inspectors of Mines.

CHAPTER VII.

NOTTINGHAMSHIRE COAL-FIELD.

Description of Coal-field and Section of Strata at Cinderhill Colliery—Analyses, Production, and Distribution of Coal by Railway—Population employed in Coal Mining in Nottinghamshire—(Resources and Duration, included in the Coal-field of York, Derby, and Notts).

The Nottinghamshire Coal-field.—This coal-field is a continuation of that of Derbyshire and Yorkshire, and Mr. W. T. Aveline, in his "Memoir of the Country around Nottingham," gives the following section, remarking that, "as in other districts, the coal formation is here an accumulation of beds of sandstone, shale-clay, and ironstone, alternating with each other. There are many beds of coal in this field lying at intervals below each other, separated by the sandstones, shales, &c., but it is only a few of these that are thick, or good enough, to be worked to a profit." *

VERTICAL SECTION OF THE NOTTINGHAM AND DERBYSHIRE COAL-FIELD.

The first part (to the Top Hard Coal) from a pit at Cinderhill.

No.	Description of Strata.	Thickness. Ft.	Thickness. In.	Depth. Ft.	Depth. In.
1	Limestone (Magnesian)	5	4	...	
2	Light blue and brown stone in beds . .	6	3	11	7
3	Blue stone.	8	5	20	0
4	Dark-pink bind	3	8	23	8
5	Dark-grey stone	0	4	24	0
6	Red stone with pebbles.	1	0	25	0
7	Clunch (usually tough clay or shale) .	1	9	26	9
8	Bind	19	0	45	9
9	Ironstone	0	3	46	0
10	Soft clunch	5	0	51	0
11	Black shale or bind	2	7	53	7
12	Clunch.	6	8	60	3
13	Bind, with bands of ironstone	40	4	100	7
14	Chillery coal	0	7½	101	2½
15	Light and dark clunch	6	0	107	2½
16	Bind	20	9	127	11½
17	Ironstone	0	2½	128	2
18	Bind	14	7	142	9
19	Soft coal	1	1½	143	10½
20	Shale bind and clunch	20	2	164	0½
21	Soft coal	2	4½	166	5
22	Clunch and bind, with bat and shale . .	18	10	185	3
23	Soft coal	1	0	186	3
24	Clunch and bind	1	0	187	3

* "Memoirs of the Geological Survey," 1861. (Quarter sheet, 71 N.E.)

No.	Description of Strata.	Thickness.		Depth.	
		Ft.	In.	Ft.	In.
25	Soft coal	1	7½	188	10½
26	Clunch and stone	9	5	198	3½
27	Bind, clunch, stone, and bat, with a little coal and ironstone	81	8½	280	0
28	Coal	3	6½	283	6½
29	Dark clunch, with bat and ironstone .	20	8	304	2½
30	Coal	0	7	304	9½
31	Shaly bind	10	1	314	10½
32	Soft coal	2	4	317	2½
33	Shale and bind	36	2	353	4½
34	Soft coal	3	4	356	8½
35	Dark clunch, with impressions . . .	3	11	360	7½
36	Soft coal	1	3	361	10½
37	Clunch and bind	45	3	407	1½
38	Coal	1	5	408	6½
39	Black shale and bind	29	7	438	1½
40	Soft coal	2	5	440	6½
41	Shale clunch, &c.	68	7	509	1½
42	Coal	3	9	512	10½
43	Shale and bind and a few small beds of ironstone	82	3	595	1½
44	Coal (hard)	2	2½	597	4
45	Clunch, bind, and shale	50	0	647	4
46	Main coal	8	2	655	6

Another section in the same district, by Mr. Aveline, gives the following as the depth and thickness of the seams and intervening strata between the "Top Hard" and the "Deep Hard Coal:"—

Description of the Strata.	Thickness.		Depth below Top Hard.	
	Ft.	In.	Ft.	In.
Bind with ironstone	25	2	...	
Coal	0	10	424	5
Clunch and bind	11	0	...	
Coal	0	10	436	3
Bat, clunch, and bind	9	9	...	
Coal (probably the Ell coal)	1	0	447	0
Bind and rock	54	0	...	
The main or deep soft coal	3	0	504	0
Bat	1	0	...	
Dark clunch and fire-clay	12	6	...	
Bind and rock	6	10	...	
The Deep Hard coal	3	6	527	10

The following section gives the chief coals below the Deep Hard Coal:—

Description of the Strata.	Thickness.		Depth below Top Hard.	
	Ft.	In.	Ft.	In.
Clunch, bind, &c.	66	0	...	
Piper coal	5	0	71	0
Bind, clunch, and other strata . . .	138	0	...	
Furnace coal	4	0	213	0
Clunch, bind, &c.	108	0	...	
Yard coal	3	0	324	0
Clunch, bind, &c.	30	0	...	
Black shale coal	5	4	359	4
Clunch, bind, &c.	459	0	...	
Kilburne coal	3	6	821	10
Depth of Kilburne coal below Top Hard coal	...		1,339	8

It is remarked that of the coals in the above sections, the only beds that are, or have been, worked in this district are the Top Hard, or "Rifler," Waterloo, Main Soft, Lower Hard, and Piper coals; and further, that clunch usually means tough clay or shale; binds, shaley clay often blue, and bat, carbonaceous shale.

Analysis of Coal.—The coal raised in the neighbourhood of Worksop, at the Shireoaks Colliery, examined by Mr. Charles Tookey in Dr. Percy's laboratory, shows the following constituents:—

RESULTS TABULATED.

Carbon	77·40
Hydrogen	4·96
Oxygen	7·77
Nitrogen	1·55
Sulphur	0·92
Ash	3·90
Water	3·50
	100·00

The ash remaining being described as bulky and slightly pink in colour; the coal, on coking, yielding 63·18 per cent.

Other coals, extensively worked by the Butterley Company, in Notts and Derby, are known as the "Upper Hard Coals" and the "Lower Hard Coals," the former described "as excessively hard and containing much mineralized charcoal in the jointings, with thin strata of bright coal occasionally intervening; the second closely resembles the first, but contains more iron pyrites."* The

* Appendix, Third Report Coal Suited to the Steam Navy, p. 29.

coal, in the first analysis, was obtained from the Portland Colliery of the above-named company, situated at Kirkby, in Ashfield, Notts, at a depth of 180 yards from the surface, the vein, being irregular, varying in thickness from 3 feet 6 inches to 5 feet. The second, the "Lower Hard Coals," examined was obtained from the Langley Colliery of the same company, situated near Heanor, the seam having a thickness of three feet; the following gives the results :—

Constituents.	Portland Upper Hard.	Langley Lower Hard.
Carbon	80·41	77·97
Hydrogen	4·65	5·58
Nitrogen	1·59	0·80
Sulphur	0·86	1·14
Oxygen	11·26	9·86
Ash	1·23	4·65
	100·00	100·00
Specific gravity	1·301	1·264
Per centage of Coke	60·90	54·90

It is remarked of these coals that they light easily, and when thrown on the fire make a crackling noise. They burn freely, leaving a white-coloured ash, the "Lower Hard" more than the "Upper Hard," and both requiring the frequent use of the rake to prevent the choking of the draught in the furnace. The clinker, though considerable, did not adhere to the fire-bars, and when the stoking or charging the fire took place it was found much smoke was evolved.

Production and Distribution of Coal.—In the year 1816 the quantity of coal carried by inland navigation in Nottinghamshire was 494,665 tons; in Derbyshire, 942,218 tons, and in Yorkshire, 2,563,626 tons, the produce of this great coal-field, extending through the above-named counties. Indeed, these quantities may be regarded as the output of the collieries in operation at the time.

The next return, for the year 1854, gives the output of seventeen collieries in Nottinghamshire as 813,474 tons, the production being doubled since the year 1816. In 1855 the number of collieries increased to 20, and the output fell off to 809,400

tons. Subsequently the number of collieries and production of coal in the Nottinghamshire coal-field has been as under :—

Year.	No. of Collieries.	Coal Raised.	Year.	No. of Collieries.	Coal Raised.
		Tons.			Tons.
1816	...	494,665	1867	24	1,575,000
1854	17	813,474	1868	27	1,508,439
1855	20	809,400	1869	26	1,575,450
1856	24	*	1870	27	2,115,372
1857	23	*	1871	27	2,469,400
1858	23	*	1872	28	*
1859	23	*	1873	34	*
1860	21	*	1874	45	3,127,750
1861	22	*	1875	46	3,250,000
1862	21	732,666	1876	48	3,415,100
1863	21	750,000	1877	47	3,895,750
1864	21	796,700	1878	41	4,107,350
1865	21	1,095,500	1879	41	4,249,242
1866	25	1,600,000	1880	44	4,432,393†

The development of the Nottinghamshire coal-field is greatly aided by the ample facilities provided by several important systems of railways and canals. The coal-field on the south-west border of the county is traversed by the Midland Railway, which enters the county at the south-west corner running through the Erewash Valley along the border to Codnor, in Derbyshire, and on to Mansfield; a branch coming from Derby runs along the valley of the Trent to Nottingham and from Newark to Lincoln, with branches from Nottingham to Mansfield and Southwell. The impulse given to the coal trade of Nottinghamshire appears in the railway returns. The Midland Railway, in 1863, carried from Nottinghamshire 83,932 tons, and in subsequent years the following quantities, according to returns of "Mineral Statistics:"—

Year.	Coal Carried.	Year.	Coal Carried.
	Tons.		Tons.
1864	188,753	1873	967,000
1866	197,873	1874	1,005,587
1867	180,506	1875	1,019,793
1868	191,796	1876	1,222,417
1869	283,548	1877	1,295,479
1870	471,118	1878	1,506,936
1871	574,796	1879	1,625,471
1872	689,407	1880	1,614,377

* Production included in Derbyshire.

† Report H.M. Inspector of Mines.

In the year 1880, and previous years, the following quantities of coal, the produce of the Nottinghamshire collieries, have been used by the Midland Railway Company for locomotive purposes. Side by side is given, for the same years, the total quantities of coal used for similar purposes by the Midland Company throughout their railway system :—

Year.	Nottingham Coal.	Total Coal Used.
	Tons.	Tons.
1876	87,392	548,817
1877	126,611	612,886
1878	130,457	575,117
1879	145,627	656,340
1880	94,641	707,185

The Manchester, Sheffield, and Lincolnshire Railway carried small quantities of coal from Nottinghamshire between the years 1872 and 1878, when the traffic appears to have ceased; the tonnages, though unimportant, were as under, amounting in 1872 to 4,397 tons :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1873	4,234	1876	3,869
1874	4,056	1877	5,622
1875	3,838	1878	9,601

During the existence of the association known as the "Associated Coal Owners of Derbyshire, Nottinghamshire, and Leicestershire," information was available showing the respective sales, by railway and canal, of coal, the produce of collieries situated in Nottinghamshire and the adjoining counties. The Association was dissolved in 1877, but up to that date the movement of coal in each year from this coal-field was as under :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1869	121,392	1873	276,645
1870	283,548	1874	163,765
1871	227,987	1875	86,315
1872	265,008	1876	134,777

Population Employed in Coal mining in Nottinghamshire.— The total number of persons of all ages employed in the year 1854

was 3,071; the output of the coal mines amounting to 813,474 tons. In 1873 the numbers were 10,366, of these 7,755 were engaged in underground operations, and 2,611 above ground, the total coal produced in the coal-field amounting to 2,890,929 tons. The numbers employed in subsequent years, and the output of the collieries, and produce per man, appear in the annexed statement:—*

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	7,755	2,611	10,366	2,890,929	279
1874	9,099	3,129	12,228	3,125,176	255
1875	9,618	3,095	12,713	3,265,368	278
1876	10,294	3,311	13,605	3,582,995	264
1877	10,182	3,210	13,392	3,877,322	289
1878	10,633	3,278	13,911	4,106,392	295
1879	10,772	3,459	14,231	4,316,954	303
1880	10,357	3,235	13,592	4,432,393	326

The maximum number of colliers employed in our coal-fields was in the year 1875, when of the 535,845 engaged, 427,017 were underground, and 108,828 above ground; since that date, in most districts, the numbers employed have diminished. In Nottinghamshire, however, the numbers have gone on increasing, and the efficiency of the collier appears in the high average of coal raised by each individual in 1880, compared with 1873 and intervening years.

Of the 14,281 persons employed in coal-mining operations in the year 1879 Her Majesty's inspectors give the following analysis of their respective ages:—

All Ages.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
From 12 to 13 . .	58	...	58
,, 10 to 13 .	...	14	14
,, 13 to 16 . .	975	225	1,200
Above 16 . .	9,739	3,220	12,959
Total .	10,772	3,459	14,231

The resources and probable duration of the Nottinghamshire coal-field are considered in the great coal-field of Yorkshire, Derbyshire, and Nottinghamshire.

* Reports of H.M. Inspectors of Mines.

CHAPTER VIII.

LEICESTERSHIRE COAL-FIELD.

Description of Coal-field—Section in the Moira and Coleorton Districts—Analyses, Production, and Distribution of Coal—Population Employed in Coal Mining—Resources and Probable Duration of Coal-field.

The Leicestershire Coal-field, as described by Professor Hull, F.R.S., occupies an irregular-shaped area south of the valley of the Trent, and bounded by strata of New Red Sandstone age, except on the north-eastern side, which is occupied by the ancient shales and porphyries of Charnwood Forest, of Cambrian age. The coal-field he divides into three districts: Moira, occupying the west; Ashby de la Zouch, the centre; and Coleorton, the east, the carboniferous series of the district being thus divided :—

1. *Upper Sandstone.*
2. *Middle Coal Measures.*
3. *Lower Coal Measures.*
4. *Millstone Grit.*
5. *Yoredale Series and Carboniferous Limestone.*

In the Middle Coal Measures are numerous seams of coal, ten of which, exceeding two feet in thickness, are workable, and give an average thickness of from 40 to 45 feet of solid coal. The annexed section shows the order of occurrence of the principal coal seams in the Moira and Coleorton districts :—

Moira District (West).	Ft.	In.	Coleorton District (East).	Ft.	In.
Ell Coal	3	8	Stour Smut	4	9
Dicky Gobbler . . .	3	6	Swannington	3	7
Block Coal	3	6	Slate Coal	4	8
Little or Four Feet . .	4	6	Coal	2	10
Cannel	3	6	Coal	3	7
Main { Over Seam / Nether Seam } . .	12	0	Main Coal	6	0
			Upper Lount	3	9
Toad	3	6	Second Lount	3	0
Little Woodfield . .	2	6	Middle Lount . . .	4	6
Woodfield	5	0	Nether Lount	4	6
Stockings	9	0	Heath End Coal and Cannel	10	0
Eureka	4	6	Lower Coal Measures .		

The total thickness of measures in the Leicestershire coal-field is at least 2,500 feet, and that part containing the principal coal beds is situated about the centre. Towards the base from 800 to 1,000 feet of unproductive coal measures occur. The main coal of the Moira district is from twelve to fourteen feet thick, that of Coleorton from six to eight feet, and it is observed by Professor Hull that, though the section in the Moira and Coleorton districts cannot be identified, yet it is highly probable, that the productive measures of each, occupy the same general position in the series.

Analyses of Leicestershire Coal.—That raised at the Ibstock Colliery, situated about eleven miles from the town of Leicester, whence the coal is sent by canal and railway to various parts of England, is described* as "Mingy or Cleft coal, with a cubical fracture, adapted for house purposes, and more particularly for steamers." The mine is 128½ yards deep, and the seam 8½ feet thick, and tolerably regular. This coal will not coke, and has been employed by some of the railway companies instead of that fuel. The sample experimented upon was of a full black colour, with a cubical fracture, and contained a considerable amount of pyrites, and but little white shale. On the grate it was found to produce a good clear fire, and with careful stoking gave off but little smoke. The coal behaves precisely like an ordinary splint, and, with a quick draught, leaves a rather large quantity of clinker, which does not, however, attach itself to the bars.

The composition of mean average samples of this coal appears in the annexed analysis, one pound of which was found to evaporate 6·63 lbs. of water at a temperature of 212° Fahr.

RESULTS TABULATED.

Carbon	74·97
Hydrogen	4·83
Nitrogen	0·88
Sulphur	1·45
Oxygen	11·88
Ash	5·99
	100·00

The specific gravity of the coal is 1·291, the per centage

* Third Report, Coals suited to the Steam Navy, pp. 22, 55. By De la Beche and Playfair, 1851.

amount of coke left being 50·80, and the average weight of a cubic foot 47·33 lbs.

The coal raised at the Whitwick Colliery, situated near Coalville, and examined by Dr. Percy, gives the composition per cent. as follows * :—

RESULTS TABULATED.

Carbon	69·00
Hydrogen	4·35
Oxygen and Nitrogen	10·78
Sulphur	0·78
Ash	5·42
Water	9·67
	100·00
Coke	58·14

It is observed by Dr. Percy that the coke is firm and compact, the flame yellow, slightly smoky, and the colour of the ash pinkish-white.

Production of Coal in Leicestershire.—The output of the coal mines of this coal-field, in 1816, was 176,665 tons, in 1854 the output of eleven collieries in operation was 439,000 tons, increased in later years as under :—

Year.	Number of Collieries.	Coal Raised.	Year.	Number of Collieries.	Coal Raised.
		Tons.			Tons.
1855	11	425,000	1867	11	1,150,000
1856	14	632,478	1868	11	†608,088
1857	14	698,750	1869	10	650,700
1858	14	750,000	1870	11	599,450
1859	14	800,000	1871	12	699,900
1860	14	730,000	1874	24	1,100,465
1861	11	740,000	1875	25	1,154,619
1862	10	696,024	1876	27	1,005,000
1863	10	805,750	1877	27	1,149,590
1864	10	890,500	1878	28	1,020,500
1865	11	965,000	1879	27	1,035,016
1866	11	866,560	1880	27	1,063,382

Distribution of Coal.—The Midland Railway, in the year

* Percy's "Metallurgy," Fuel, p. 569.

† In previous years the following collieries were included in the Leicestershire return, they are now included in Derbyshire—Bretby Gresley, Granville Stanton, Cadley Hill, and Swadlincote.

1856, carried 487,230 tons of coal, the output of the Leicestershire collieries, and distributed it at various stations over their system; the returns of subsequent years are as follows:—

MIDLAND RAILWAY RETURNS.

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1857	520,514	1869	777,603
1858	634,471	1870	864,273
1859	648,133	1871	966,830
1860	717,633	1872	1,017,201
1861	696,258	1873	1,162,087
1862	705,275	1874	1,074,816
1863	766,054	1875	1,049,664
1864	879,191	1876	1,106,456
1865	843,928	1877	869,785
1866	865,240	1878	987,087
1867	920,476	1879	954,770
1868	777,603	1880	1,054,433

The quantity of coal carried in 1880 was 1,054,433 tons. Beyond the above tonnages small quantities, not exceeding a few thousand tons of locomotive coal, are carried annually for consumption on the Midland system. The total increase in the movement of Leicestershire coal since 1857 has exceeded 100 per cent., the greatest increase being in the year 1873, since which a diminution is shown. The revival of trade, however, during the past year shows an improvement; the returns being in excess of previous years.

Some interesting particulars are found in the annual reports of the Associated Coal Owners, showing the total sales of coal in Leicestershire by railway and canal; the sales in 1866 amounted to 658,876 tons. As these returns throw considerable light upon the movement of Leicestershire coal, they will be interesting, as indicating the extent of the industry in the years named:—

Year.	Quantities.	Year.	Quantities.
	Tons		Tons.
1866	658,876	1872	426,574
1867	596,988	1873	381,531
1868	536,294	1874	392,937
1869	559,377	1875	302,721
1870	462,427	1876	213,574
1871	434,716		

These quantities, it should be observed, do not include the local or land sales, nor coals used for iron-making purposes, but refer exclusively to railway and canal sales.

The London and North Western Railway are also carriers of coal from Leicestershire; the quantities, however, have never been considerable, and do not increase. For a few years they carried to stations on their own line, and passed over to other lines, the following tonnages:—

Year.	Conveyed on Main Line.	Passed over to Other Lines.	Total Carried.
	Tons.	Tons.	Tons.
1873	52,237	6,932	59,169
1874	33,607	...	33,607
1875	19,009	...	19,009
1876	12,361	185	12,546
1877	23,302	1,587	24,889
1878	32,643	2,400	35,043
1879	43,256	3,256	46,512
1880	41,700	3,138	44,838

Some coal is also carried by the Great Northern Railway from Leicestershire to stations between London and Hatfield, and Welwyn and Peterboro'. The quantity carried in 1869 was 6,321 tons; in later years as under:—

Year.	Quantities	Year.	Quantities.
	Tons.		Tons.
1869	6,321	1875	1,254
1870	6,561	1876	1,104
1871	1,827	1877	1,045
1872	1,231	1878	2,308
1873	1,773	1879	1,566
1874	1,057	1880	1,829

Population Employed in Coal Mining in Leicestershire. —In the year 1854 there were 1,646 persons thus engaged; in 1873 the number increased to 3,837, of whom 3,038 were under ground, and 799 above ground; the output of coal amounting to 832,504 tons, compared with 439,000 tons in the year 1854. The particulars for the eight years ending 1880 appear in the subjoined table,* with the average production per man in each year:—

* Reports H.M. Inspectors of Mines.

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	3,038	799	3,837	832,504	217
1874	3,896	982	4,878	1,101,402	225
1875	3,983	1,080	5,063	1,170,460	231
1876	3,435	1,145	4,580	893,204	195
1877	3,679	1,117	4,796	1,049,594	218
1878	3,188	1,089	4,277	1,021,497	239
1879	3,493	1,076	4,569	1,103,294	241
1880	3,213	1,076	4,289	1,063,382	248

Of the persons employed in 1879, the following is an analysis of the respective ages of those engaged under and above ground :—

Ages.	Under Ground.	Above Ground.
	Nos.	Nos.
From 12 to 13 . .	25	...
,, 10 to 13	...	6
,, 13 to 16 . .	290	79
Above 16	3,178	991
Total . .	3,493	1,076

Resources of the Leicestershire Coal-field and probable Duration.—The total available amount of coal in this coal-field, to depths not exceeding 3,000 feet, allowing for necessary deductions, is 836,799,734 tons. From the Report of the Coal Commission, prepared by Mr. J. T. Woodhouse, the Moira and Coleorton districts are estimated to contain the following quantities, making up the total above referred to as available :—

Name of District.	Tonnage.		
	Total estimated Tonnage in the District.	Tonnage remaining unworked.	Net Tonnage available for consumption.
	Tons.	Tons.	Tons.
Outside the Permian,			
Moira	825,155,925	775,652,338	436,304,428
Coleorton	146,418,084	108,303,063	60,920,465
Proved Sub-Permian,			
Moira	35,642,781	31,746,710	17,857,518
Coleorton . . .	595,010,079	571,941,921	321,717,323
Total . .	1,602,226,869	1,487,644,032	836,799,734

In the year 1870 the total production of Leicestershire was 599,450 tons, the year of greatest production being 1875, when 1,154,619 tons were produced, since which date a falling off appears in the output, that in 1879 being 1,035,016 tons. Deducting the output of the ten years ending 1879 there remains about 826,799,734 tons, sufficient to afford supplies, at the rate of output in 1879, for 799 years, and, with increased production, for a less period.

The quantity of coal raised in Leicestershire in 1880, according to the returns of H.M. Inspectors of Mines, was 1,063,382 tons, showing a decrease compared with the previous year of nearly 39,000 tons.

CHAPTER IX.

WARWICKSHIRE COAL-FIELD.

Description of Coal-field and Succession of Strata at Griff Colliery—Production and Distribution of Coal—Cost of Production and Prices—Population Employed in Coal Mining—Resources and probable Duration of Coal-field.

The Warwickshire Coal-Field.—This coal-field extends in a direction bearing south-east to north-west in a narrowing band, by Atherstone and Nuneaton, from the hamlet of Wyken in the immediate neighbourhood of Coventry, to the village of Polesworth in the northern part of the county. The length is between 15 and 16 miles, and in the south, near the Hawkesbury railway station and from thence to Baddesley Ensor, it maintains an average width of from one to two miles. At Baddesley Ensor it widens out, exceeding four miles from east to west, and continues about the same width as far north as Shuttington. The following formations enter into the structure of the district:—

Stratified Rocks:
- The Lias.
- The Trias or New Red Sandstone.
- The Permian Rocks.
- The Coal Measures.

Igneous Rocks, Greenstone.

The Coal Measures, the lowest division of the stratified rocks, consist of:—

Sandstones and Shales.
Upper Coal Measures.
Lower Coal Measures.
Millstone Grit.

The sandstones and shales, occupying the top of the coal measures, have a thickness of 50 feet, at the base of which is a thin bed of limestone, ranging in thickness from two to three feet, and known as the "Spinorbis Limestone." The upper division of the coal measures, 1,400 feet in thickness, contains

five workable seams of coal, which occur near the middle of the series. At the northern end of the coal-field these seams are separated by about 120 feet of shales and sandstones, all decreasing in thickness southwards, while the coal seams remain nearly the same. The following shows the order of the coals, and the thickness of strata between each seam, from a section taken at the Griff colliery north of Bedworth :*—

SUCCESSION OF STRATA.

	Ft.	In.
Four-foot Coal	3	0
Intermediate measures	51	0
Two-yard Coal	6	0
Rider Coal	2	0
Parting	9	0
Bare Coal	4	2
Intermediate measures	72	0
Slate Coal	10	0
Intermediate measures	84	0
Seven-foot Coal	5	9

These coal seams crop out on the surface to the east side of the coal-field at the north end near Polesworth, and take a direction south to Wykin near Coventry, where they lie concealed by overlying New Red Sandstone, which rests unconformably upon them.

In the southern part of the coal-field, in the neighbourhood of Bedworth and Hawkesbury, the whole of the coals come together, forming one thick seam, with thin partings of fire clay, whereas in the northern part of the coal-field, as previously stated, in the neighbourhood of Tamworth, Polesworth, and Baddesley, the same beds of coal are widely separated, the intermediate strata of sandstones and shales having thickened out.

The Lower Coal Measures attain a thickness of nearly 1,500 feet, and are barren of coal seams. It was in the shales of the lower part of this series at Hartshill Hays, that manganese was formerly wrought, the red colour of the rocks being probably due to the presence of the iron mixed with that mineral disseminated through them. At the base of the coal measures occurs the Millstone Grit, the lowest part of the carboniferous formation, consisting of a hard silicious quartz rock, with thin bands of interstratified shale, the whole exceedingly altered, and traversed along the strike by intrusive lines of Greenstone.

* "Warwickshire Coal-field," by H. H. Howell, F.G.S.

There are a few ironstone measures in this coal-field, worked but to a limited extent and yielding nine cwts. to the square yard; the ironstone giving on analysis upwards of 40 per cent. of metallic iron.

Production and Distribution of Coal. — Several collieries existed in Warwickshire towards the close of the last century, chiefly in the neighbourhood of Bedworth, Griff, Chilvers Coton, Oldbury, and extending in the same line near to Atherstone, Polesworth, and Wilncot, the coal obtained being described as of a sulphurous quality, making hot durable fires and being sold at from three pence to five pence per hundred weight at the pits.*

The production in the year 1816 amounted to 162,962 Newcastle chaldrons, equivalent to 431,849 statute tons.† In 1854 for the first time appeared the number of coal mines in Warwickshire and the output of coal; since that date the particulars are as follows:—

Year.	Collieries.	Coal Raised.	Year.	Collieries.	Coal Raised.
	Nos.	Tons.		Nos.	Tons.
1854	15	255,000	1868	16	624,850
1855	17	262,000	1869	16	585,630
1856	16	335,000	1870	18	647,540
1857	16	398,000	1871	18	723,600
1858	17	356,500	1872	19	‡750,000
1859	17	355,750	1873	24	‡800,000
1860	17	545,000	1874	29	851,500
1861	16	647,000	1875	31	799,750
1862	16	678,000	1876	29	884,750
1863	16	685,500	1877	34	930,850
1864	16	764,000	1878	32	1,025,450
1865	16	859,000	1879	31	1,060,016
1866	15	775,000	1880	31	1,101,386
1867	15	880,850			

The distribution is mainly effected by railway and canal. The railways form a close network through the county and coal-field, the London and North Western, Great Western, and Midland coming into Birmingham, while the canals, which are numerous, give access to the Trent, the Mersey, the Thames,

* "General View of the Agriculture of the County of Warwick." By Mr. John Widse, 1794.
† Coal Commission Report, vol. iii., pp. 40, 41.
‡ Estimated production. Returns for those years included in Derbyshire, &c.

and the Severn; indeed the greater part of the county and the coal-field is intersected by canals. The London and North Western between 1854 and 1868 carried the following tonnages of coal from Warwickshire:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1854	196,332	1864	151,535
1855	150,000	1865	152,881
1859	54,000	1866	159,010
1862	98,280	1867	211,144
1863	156,804	1868	183,346

For subsequent years the coal carried by the London and North Western Railway appears in the annexed table, distinguishing that forwarded to stations on their own line, from that passed on to other railway lines:—

Year.	London and North-Western.	To Stations on other Lines.	Total.
	Tons.	Tons.	Tons.
1868	159,348	23,998	183,346
1869	145,849	38,037	183,886
1870	148,571	39,360	187,931
1871	173,663	38,716	212,379
1872	178,889	50,126	229,015
1873	187,377	61,073	248,450
1874	128,874	85,250	214,124
1875	127,702	80,542	208,244
1876	146,319	101,991	248,310
1877	145,178	103,960	249,138
1878	184,275	124,245	308,520
1879	177,465	118,970	296,435
1880	171,673	134,579	306,252

The Midland Railway also contributes to the distribution of coal, extending from Derby through Tamworth, and from Leicester to Nuneaton and Whitacre junction, and thence to Birmingham; other branches bringing it in communication with the London and North Western line. The Midland Railway carried the quantities stated below in each of the following years:—

Year.	Coal Carried.	Year.	Coal Carried.
	Tons.		Tons.
1857	28,010	1869	62,903
1858	28,907	1870	75,863
1859	38,489	1871	86,826
1860	20,000	1872	119,122
1861	*	1873	158,799
1862	*	1874	162,512
1863	79,809	1875	174,442
1864	85,922	1876	165,085
1865	86,069	1877	164,279
1866	74,751	1878	233,022
1867	60,134	1879	295,673
1868	60,093	1880	308,697

During the year 1880 the quantity of coal carried by the Midland Railway amounted to 308,697 tons, showing an increase of 13,024 tons, compared with the previous year.

Cost of Production and Prices.—Much of the coal raised in Warwickshire is used for domestic purposes, the small being employed for lime and brick burning. When stacked and exposed to the weather, a considerable amount of small softened coal is found after the removal of the bulk. In 1830, Mr. Thomas Smith gives the average profit per ton on working the best coals as 3*s*. 10*d*. per ton, the average price being 10*s*. 10*d*.; the real average being reduced by the lower price of the small coal to about 9*s*. 3*d*. per ton and the profit to 2*s*. 3*d*. per ton, the cost of getting, work, and royalty in all cases at that period amounting to about 7*s*. per ton.

The entire produce per acre of all the coal seams worked, amounting to 14,521 tons of coals, and 1,086 tons of lumps or cobbles, giving a total of 15,607 tons per acre, the total quantity left in the workings in the form of ribs, being about 1,612 tons per acre. Upon the usual mode of working at this period, each man got per day two tons three cwts. of coal; each ton costing, in loading, drawing out, banking, and loading into waggons, from 1*s*. 3*d*. to 1*s*. 6*d*., timber, powder, and sundries included.†

In the year 1870‡ the following were the prices at the pit's mouth at the undermentioned collieries in Warwickshire:—

Bedworth, average, 6*s*. 9*d*.
Glascote, best, 10*s*.; slack, 2*s*. 6*d*.
Griff, average, 7*s*. 6*d*.
Peel, best, 6*s*. 8*d*.; slack, 3*s*. 4*d*.
Wyken, best, 6*s*. 2*d*.; slack, 3*s*. 4*d*.

* Not separately distinguished.

† Miner's Guide, 1836, p. 141.

‡ Coal Commission Report, vol. iii., Appendix, p. 212.

Ten years later the average, highest, and lowest prices of coal and slack at the pit's mouth were as follows:—

Prices.	1880.		1879.	
	Coal.	Slack.	Coal.	Slack.
	s. d.	s. d.	s. d.	s. d.
Average	6 6	4 6	7 2	4 0
Highest	7 5	5 6	9 0	5 6
Lowest	6 0	2 0	6 0	2 0

Population employed in Coal Mining in Warwickshire.— In 1854 there were 1,646 persons engaged in coal mining, producing 255,000 tons of coal. Twenty-five years later the production of the coal-field was fourfold, exhibiting remarkable progress; the details of the eight years ending 1880 are as follows, with the output of the coal-field and the average produce per man.*

Year.	PERSONS EMPLOYED.		Total.	Coal raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	3,578	1,070	4,648	832,387	179
1874	3,659	1,134	4,793	852,774	178
1875	3,505	1,099	4,604	803,851	174
1876	3,453	1,124	4,577	896,246	195
1877	2,990	1,022	4,012	922,879	230
1878	3,159	1,032	4,191	1,022,915	243
1879	3,244	1,020	4,264	1,054,759	247
1880	3,207	986	4,193	1,101,386	263

The steady working of the mines appears in the average output, giving an increase in the eight years of 84 tons, equal to 46 per cent. per man.

The ages of all employed in the year 1879, under and above ground, were as follows:—

Ages.	Under Ground.	Above Ground.
	Nos.	Nos.
From 12 to 13 . . .	17	...
,, 10 to 13	...	3
,, 13 to 16 . . .	239	76
Above 16	2,988	941
Total .	3,244	1,020

* Reports of H.M. Inspectors of Mines.

Resources of the Warwickshire Coal-field and probable Duration.—The total acreage of coal in this coal-field to a depth less than 3,000 feet has been estimated by Mr. J. T. Woodhouse at 163,617 acres, of which 153,909 acres remained unworked in the year 1870. This acreage is thus distributed:—

Name of District.	Total Acreage.	Acreage Unworked.
Outside the Permian .	161,196	152,785
Proved Sub-Permian .	2,421	1,124
Total acres .	163,617	153,909

Converting the total acreage into tons, at the estimated rate of 1,556 tons per acre per foot thick, there existed originally in this coal-field 995,511,270 tons, the acreage unworked amounting to 815,382,625 tons; and of this quantity there remains—due allowance being made for coals which cannot be worked from various causes—458,652,714 tons. The details of these enumerated quantities are thus given in the Coal Commission Report:*—

District.	Total estimated Tonnage in Warwickshire.	Tonnage remaining unworked.	Net Tonnage available for consumption.
	Tons.	Tons.	Tons.
Outside the Permian .	880,033,153	809,730,113	455,473,182
Proved Sub-Permian .	115,478,117	5,652,512	3,179,532
Total .	995,511,270	815,382,625	458,652,714

The total quantity of coal wrought during the ten years ending 1879 amounts to 8,473,456 tons; deducted from the original estimate leaves 450,179,258 tons available for future consumption. This quantity, taking the average of the ten years (847,345 tons), would afford sufficient supplies for 531 years hence, while taking the production of 1879 (1,060,016 tons), the exhaustion of the coal-field would occur in about 425 years. It should be observed that the estimate of coal in Warwickshire includes all workable seams not exceeding a depth of 3,000 feet, and that the output of the coal-field has quadrupled in a quarter of a century, the production of 1880 exceeding that of the previous year by 46,627 tons.

* Vol. i. p. 31.

CHAPTER X.

SHROPSHIRE COAL-FIELDS.

Description of Coal-fields, and Section of Strata at Coalbrookdale—Analyses, Production, and Distribution of Coal—Prices and Cost of Production—Population employed in Coal and Iron Mining—Resources and probable Duration of Coal-field.

The Shropshire Coal-fields.—The coal deposits of Shropshire are not found occurring in one unbroken area, like those of the Great Midland coal-fields of Yorkshire and Derbyshire, but rather in several detached tracts or areas, all referable, geologically, to the same age. Of these the most important is the coal-field of Coalbrookdale; the others are those of Shrewsbury, Oswestry, the Clee Hills, and the Forest of Wyre.

The Coalbrookdale coal-field has an area of twenty-eight square miles, and extends from the Severn, near Broseley and Ironbridge on the south, having an irregular western boundary at Coalbrookdale, Little Wenlock, and the faults a mile or two to the eastward of Wellington, where it has its greatest width of about four or five miles; it then, becoming gradually narrower, extends to Lilleshall and Church Aston. The greatest thickness of the coal measures in this area exceeds 1,200 feet, in which occur several important seams of coal. Professor Hull gives the following succession of coal seams, and their varying thickness in the Coalbrookdale coal-field.*

COAL SEAMS.		THICKNESS. Ft. In.	Ft. In.
1. Chance Pennystone Coal	Found only at north end of coal-field.		
2. Fungus Coal			
3. Gur Coal			
4. Top Coal.	from	4 0 to	4 6
5. Half-yard Coal			1 6
6. Double Coal		5 0 to	6 0
7. Yard Coal		2 6 ,,	3 0
8. Big Flint Coal		3 0 ,,	4 6
9. Stinking Coal		3 0 ,,	4 0
10. Clunch Coal			2 0
11. Two-foot and Best (with parting)			3 4
12. Randle and Clod Coal		4 0 to	5 0
13. Little Flint Coal		1 6 ,,	2 3

* "Coal-fields of Great Britain," 4th edition, p. 143.

The aggregate average thickness of the seams exceeding two feet in this section, is equal to 27 feet of solid coal. It is observable that in passing from the north to the south of the coal-field the thickness of the measures and of the seams of coal diminishes considerably. This appears in the following table, showing the number of seams existing in different parts of the coal-field, and how much they vary in their dimensions in the pits referred to, the united thickness of the mass of coal in any one pit not being dependent upon the number of the seams: *—

Pits.	Thickness of Coal.			No. of Beds of Coal.
	Yds.	Ft.	In.	
Hadley	15	0	0	16
Sneds Hill . . .	14	2	2	12
Malinslee . . .	11	0	10	13
Langley	11	2	6	11
Dawley	14	0	0	16
Lightmoor . . .	13	2	0	17
Madeley . . .	10	2	10	24
Broseley	7	0	9	13

The Shrewsbury coal-field is of less extent than that of Coalbrookdale, and forms a narrow band from the base of Haughmond Hill, east of Shrewsbury, to the river Severn, near Alberbury, a distance of eighteen miles, its greatest width in any one place not exceeding one mile. In the lower part of the coal measures there are two or three seams of coal worked, but only to a limited extent. The other coal areas of Oswestry and the Forest of Wyre possess some workable seams of coal, but their production is not very considerable. They are thus referred to by a writer in the *Colliery Guardian* † familiar with the district: "The seam won at Highley is not quite 4 feet thick of good coal; there is a roof of clod some 2 feet 9 inches thick, and a bat of 9 or 10 inches. At Billingsley this same seam, at a depth of 155 yards, has a thickness of 6 feet 9 inches gross, and they have in addition a 'half-yard,' 'four-feet,' and a 'two-feet' seam, besides the top or sulphur coal; they also have seams of fire-clay (one over the Brooch coal) and ironstone, which do not appear at Highley." Billingsley is situated some two miles to the north-west of the last-mentioned

* Coal Commission Report, Vol. iii., p. 122.
† Vol. xxxviii., Nov. 28, 1879, p. 854.

place, and it appears that the seams of coal between the two places thin out to the east of the coal-field.

Analysis of the Coal. — The following coals, extensively employed in the iron-works of the district, give, upon examination, the annexed results, each 100 parts of coal consisting of—

Name and Locality.	Volatile Matter.	Carbon.	Ashes.	Specific Gravity.
Fungus Coal (Donnington) .	34·8	63·8	1·4	1·245
Top Coal ,, . .	37·1	62·1	0·8	1·267
Flint Coal (Madeley) . .	34·6	64·9	0·5	1·269
Sulphur Coal (Ketley) . . .	41·1	56·1	2·8	1·292
Best Coal (Madeley) . .	34·3	64·4	1·3	1·273
Clod Coal ,, . . .	37·3	62·7	1·0	1·264
Little Flint Coal (Broseley) .	38·3	61·1	0·9	...

The Top, Yard, Double, and Big Flint coals, are largely employed for manufacturing purposes; the Clod Coal and Little Flint being most valued for iron smelting, while the "Fungus Coal," chiefly confined to the northern area of the coal-field, is alike useful for all purposes where coal is employed.

Production and Distribution of Coal. — The earliest information appears for the year 1854, when the 48 collieries in the county raised 1,080,000 tons, which were chiefly employed in the iron works and for local consumption. Since 1854, the number of collieries and production of coal are shown in the following table:—

Year.	Collieries.	Coal.	Year.	Collieries.	Coal.
	No.	Tons.		No.	Tons.
1855	56	1,105,250	1868	64	1,495,500
1856	55	752,100	1869	59	1,392,862
1857	55	750,000	1870	59	1,343,300
1858	57	749,360	1871	59	1,350,000
1859	59	765,750	1872	60	*
1860	68	850,000	1873	60	1,570,000
1861	66	829,750	1874	65	1,187,950
1862	65	1,029,750	1875	64	1,225,785
1863	66	1,150,000	1876	64	1,054,049
1864	66	1,150,000	1877	61	927,580
1865	69	1,135,000	1878	63	830,575
1866	63	1,220,000	1879	62	854,380
1867	62	1,558,500	1880	66	905,000

* Included in the returns of production for North Staffordshire and Cheshire.

To the distribution of the Shropshire coal, the London and North Western Railway principally contributes: in 1863, the earliest return is met with, when 88,167 tons were carried out of the county, and in 1865 but 75,230 tons; the Great Western Railway, in the same year, carrying 795 tons into South Staffordshire. The quantities carried in later years appear as follows, together with that passed over to other lines by the—

LONDON AND NORTH WESTERN RAILWAY.

Year.	To Stations on Line.	To other Lines.	Total carried.
	Tons.	Tons.	Tons.
1867	45,936	...	45,936
1868	59,186	...	59,186
1869	116,020	1,777	117,797
1870	113,947	3,370	117,317
1871	109,519	5,077	114,596
1872	105,461	4,903	110,364
1873	100,354	7,226	107,580
1874	99,532	7,559	107,091
1875	99,529	6,818	106,347
1876	88,374	3,688	92,062
1877	101,552	3,090	104,642
1878	82,862	2,845	85,707
1879	65,230	3,885	69,115
1880	103,502	2,831	106,333

Prices and Cost of Production. — Forty years ago this question was carefully considered, both as regards coal and ironstone;* the Fungus Coal, the uppermost in the series, yielding 15 cwts. of marketable coal to each cubic yard, of which 10 cwts. were large coal, 2 cwts. lumps, and 3 cwts. slack. At this period the cuttings, or perpendicular channellings, to facilitate the bringing down of the coals, were situated at from four to five yards distance from each other, and to bring down and clear away the usual line of 30 yards in one day cost £2 3*s*., distributed as follows:—

	£	*s.*	*d.*
3 holers at 2*s*. 9*d*. per day	0	8	3
3 brushers and coggers, 3*s*. 3*d*.	0	9	9
Drawing out	1	5	0
Total	£2	3	0

and producing of coals, 17 tons; lumps, 3 tons 8 cwts., and slack, 5 tons 2 cwts., in all a total of 25 tons 10 cwts. The cost

* Thomas Smith's "Miner's Guide," 1836, p. 118.

and production of each seam of coal (per ton) appear in the subjoined statement:—

Name of Coal Seams.	Thickness.		Cost per ton.					
			Coals.		Lumps.		Slack.	
	Yds.	Ft.	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
Fungus Coal . . .	1	0	2	0½	1	2	1	0
Stone	1	1	1	11	1	2	1	0
Top	1	2	1	7	1	2	1	0
Double	2	0	1	9	1	2	1	0
Yard	1	0	2	0	1	2	1	0
Flint	1	2	1	10½	1	2	1	0
Randle and Clod . .	2	1	1	9	1	2	1	0
Total .	11	0	12	11	8	2	7	0
Average cost			1	10	1	2	1	0
Dead work			2	0	2	0	2	0
Royalty			0	8	0	4	0	2
Average cost per ton .			4	6	3	6	3	2

The same authority, considering the yield per acre of the above seams of coal, estimates the produce as follows, to which is added the royalty per ton, and the total royalty per acre:—

	Produce per Acre.	Royalty.		Amount of Royalty.		
	Tons.	*s.*	*d.*	£	*s.*	*d.*
Coals	26,620	0	8	887	6	8
Lumps	5,324	0	4	88	14	8
Slack	7,986	0	2	66	11	0

Again, the average quantity of coal wrought by each man per day is stated as follows:—

Coal Seams.	Coals.			Lumps.			Slack.		
	Tons.	Cwts.	Qrs.	Tons.	Cwts.	Qrs.	Tons.	Cwts.	Qrs.
Fungus	2	16	2	0	11	1	0	17	0
Stone	3	4	2	0	12	3	0	19	1
Top	5	13	1	0	0	0	1	8	2
Double	3	15	2	0	15	0	1	2	2
Yard	3	0	0	0	12	0	0	18	0
Flint	3	6	2	0	13	1	1	0	0
Randle and Clod . .	5	14	1	1	2	3	1	14	1
Total per day .	27	10	2	4	7	0	7	19	2
Average per day .	3	18	2	0	12	2	1	2	3

The aggregate of these totals gives an average of 5 tons 13 cwts. 3 qrs. got by each miner per day of coal from the above-named seams of coal.

Following the prices obtained per ton at the pit's bank in 1868, the annexed shows generally the average: Top Coal, at Old Park Colliery, 10*s.* 4*d.* per ton; Double Coal, 8*s.* 6*d.*; Yard Coal, 8*s.* 6*d.*; Flint, 9*s.* 6*d.* to 10*s.*; New Mine, 6*s.* 6*d.*; Two-foot, 8*s.*, and Little Flint, 10*s.* 4*d.* per ton.

Mr. T. Parton, F.G.S., in his notes on the Shropshire coal-field,* writing in the year 1868, states that at that time the cost of extracting the coal and ironstone varied according to special circumstances, and gives the annexed as the prices delivered on colliery bank as a very close approximation:—

		s.	*d.*		*s.*	*d.*
Top Coal	from	3	0	to	4	0
Double Coal	,,	2	6	,,	3	0
Yard Coal	,,	3	6	,,	4	6
Blue Flatt Ironstone	,,	7	0	,,	10	0
White Flatt Ironstone	,,	9	0	,,	11	0
Big Flint Coal	,,	3	0	,,	3	6
Penny Stone Ironstone	,,	6	0	,,	9	0
Stinking Coal	,,	3	0	,,	4	0
Two-foot and Best Coal	,,	3	0	,,	4	3
Randle Coal	,,	3	0	,,	3	6
Clod Coal	,,	3	0	,,	4	0
Little Flint	,,	4	6	,,	6	0

These prices may be regarded as the highest and lowest incurred in getting the coals and ironstones, fluctuating according to the rate of wages.

The average prices of coal and slack during the years 1878 and 1879 exhibit but little variation, and in the last-named year were quoted as follows, to which is added the highest and lowest prices ruling throughout the year:—

Year.		Average.	Highest.	Lowest.
		s. *d.*	*s.* *d.*	*s.* *d.*
1879	Coal	8 9	13 4	6 0
	Slack	3 10	5 10	2 6
1880	Coal	9 2	13 4	6 8
	Slack	4 3	6 3	2 6

Comparing these prices with those ruling in the year 1873,

* Vol. xv. "Colliery Guardian," 1868, p. 223.

known as the year of the "Coal Famine," it appears, in evidence before the Select Committee on Coal,* that in Shropshire, Cheshire, and North Staffordshire, the price of coal per ton in these districts rose from *7s. 6d.* to *20s.*, while as regards slack, which previous to the year 1872 was sold from *2s. 3d.* to *2s. 6d.* per ton, it rose in this last-named year to *10s. 6d.*; the great demand for coal at this period arising in Shropshire from the iron manufactures, and in Staffordshire from the earthenware industries.

Population employed in Coal and Iron Mining.—The number of male persons employed in coal and iron mining in Shropshire, according to official returns for the year 1854, was 5,722; of these 4,580 persons were engaged in coal mining, and 1,142 in iron mining, the yield of coal the same year being 1,080,000 tons. In later returns the persons employed are included in other districts, but when the Coal Mines Regulation Act, 1872, came into operation, and since, very complete accounts have appeared in the Reports of Her Majesty's Inspectors of Mines, showing the number engaged under ground and above ground, together with the quantities of coal raised. These details appear in the annexed table, to which is added the average tonnage of coal raised per person in each year:—

Year.	Persons Employed.			Coal raised.	Average per Man.	Total Minerals raised.†	Average per Man.
	Under Ground.	Above Ground.	Total.				
				Tons.	Tons.	Tons.	Tons.
1873	...	...	...	1,262,490	...	1,858,870	...
1874	5,635	2,487	8,122	1,188,490	146	1,623,310	200
1875	5,513	2,204	7,717	1,225,180	158	1,721,720	223
1876	4,684	1,896	6,580	1,059,740	161	1,558,840	236
1877	4,191	1,583	5,774	921,700	159	1,343,370	233
1878	3,766	1,468	5,234	827,200	158	1,195,600	213
1879	3,423	1,348	4,771	822,400	172	995,295	208
1880	3,546	1,235	4,781	905,000	189	1,168,900	244

The total of persons given as employed in coal mining also includes those engaged in raising fire-clay and ironstone; it is therefore desirable to take the total of minerals raised to follow more clearly the average produce per man, which appears in the last column.

* Mr. Thomas Wynne, H.M. Inspector of Coal Mines. Report, Coal, 1873, p. 42.
† Including coal, fireclay, and ironstone.

Resources and probable Duration of Coal-field.—In the Report of the Royal Coal Commission, the quantity of unworked coal remaining in the Shropshire field is included in the returns of South Staffordshire and East Worcestershire. It has, however, been estimated by reliable authorities that the available coal remaining in Shropshire did not exceed 20,000,000 tons in the year 1870. At the then rate of production, 1,343,300 tons, the exhaustion of the deposits may be expected at no very distant period. Since that date, however, the production has fallen off, being only 822,400 tons in the year 1879, compared with 905,000 tons in 1880, showing an increase of 82,600 tons in the last-named year.

CHAPTER XI.

NORTH STAFFORDSHIRE COAL-FIELD.

Description of Coal-field, its Extent, Area, and Succession of Strata—Coal Seams and Ironstone Measures—Cheadle Coal-field—Analyses, Production, and Distribution of Coal—Quantities Consumed in Ironworks, Potteries, Brick-works, &c.—Price of Coal and Cost of Production—Population Employed in Coal and Ironstone Mining—Resources and probable Duration.

North Staffordshire Coal-field.—This coal-field is remarkable for the number and richness of its beds of coal and ironstone. The coal-field is triangular in form, with its apex at the base of Congleton Edge, and deeply indented along its southern margin by spurs of the Permian formation, which runs far into the heart of the coal measures through the agency of faults. The coal-field has an area of 75 square miles and even more, if the coal lying under the Permian rocks to the south were included. It extends from Handford Lane End and Longton on the south, to Biddulph on the north, again from Oakmoor and Cheddleton on the east to Madeley on the west. Its resources of coal and ironstone greatly exceed that of the South Staffordshire coal-field, though smaller in its area. It has twice the thickness of workable coal, and many of the seams of coal are roofed by measures of rich argillaceous ores of iron.

The coal measures are divided into upper, middle, and lower measures; the upper series of which is barren of profitable coal, while the middle, or pottery coal and ironstone measures, 4,000 feet thick, contain no less than 40 seams of coal, besides numerous bands of ironstone. The lower division includes beds of black shales and flags, with 17 or 18 seams of coal, each having a thickness exceeding two feet. In one area of this coal-field a thickness amounting in the aggregate to 140 feet of coal exists; in another, where 24 seams of coal occur, a total thickness of 109 feet of coal has been ascertained, interstratified with numerous courses of "black band" or carbonaceous iron ore, varying from two to six feet in thickness, and crowded with the characteristic fossil shells "Anthracosia" and "Anthracomya."

The annexed section shows the order of occurrence of the several coal seams and intervening strata, with the respective thicknesses :—

COAL SEAMS AND INTERVENING STRATA.	THICKNESS. Ft.	In.
Peacock Coal	6	6
Strata	20	0
Spencroft Coal	3	9
Strata	121	0
Great Row Coal	8	0
Strata	71	0
Cannel Row Coal	5	0
Strata	54	0
Wood Mine Coal	2	0
Strata	29	0
Deep Mine Coal	2	8
Strata	361	0
Winghay Coal	4	6
Strata	377	0
Ash or Rowhurst Coal	8	0
Strata	121	0
Burnwood Coal	5	0
Strata	68	0
Golden Twist	3	6
Strata	486	0
Mossfield Coal	4	7
Strata	30	0
Coal	3	0
Strata	270	0
Birches Coal	4	6
Strata	300	0
Ten-foot Coal	6	0
Strata	102	0
Bowley Alley Coal	4	6
Strata	81	0
Holly Lane Coal	5	10
Strata	84	0
Sparrow Batts Coal	4	9
Strata	222	0
Flats Coal	3	0
Strata	108	0
Frog's Row Coal	4	6
Strata	30	0
Cockhead Coal	4	6
Strata	420	0
Bullhurst Coal	4	0
Strata	60	0
Winpenny Coal	3	0

In the northern part of the coal-field at Rugged Mow Cop, to the south of Congleton, some sixteen coal basins or coal areas, more or less separated, can be distinguished, all geologically of the same age. The resources of this coal-field are considerable, presenting a total thickness of 150 feet of coal, and an available

quantity for future use amounting to 4,826 millions of tons of coal, as ascertained by the Royal Coal Commission, allowing for necessary deductions; while if the whole of the workable seams of coal and ironstone were spread over the area of the coal-field, the solid thickness of coal would be represented by 32 feet, and the ironstone by a thickness of five feet.

The ironstone deposits of this coal-field are no less remarkable than the seams of coal; they are extremely numerous, and exist abundantly in the districts of Longton, Hanley, and Newcastle-under-Lyme. In a section of measures at the Longton Colliery of 250 yards nine distinct seams are worked. At Apedale, three miles north-west of Newcastle-under-Lyme, the principal measures occurring are the "*Black Band,*" "*Red Shag,*" "*Bassy Mine,*" and "*Red Mine,*" having a thickness respectively of four, six, seven, and nine feet. The following are the more important measures of ironstone worked, the yield varying according to the thickness and regularity of the seams.*

At Shelton the "*Red Shag,*" a black band ironstone, has a thickness, exclusive of shaly partings, of from 15 to 17 inches, lying immediately upon a seam of coal 12 inches thick; this ironstone is extensively exported in a calcined state to the districts of South Staffordshire. This ironstone contains so large a proportion of carbonaceous matter, that no coal is required for its calcination.

The "*Gutter ironstone,*" though somewhat poor at Shelton, is said to be the same measure between Chesterton and the mouth of the Harecastle tunnel, where it attains the great thickness of six feet; this stone, when mingled in certain proportions after calcination with hæmatite, is employed as a "puddle ore."

The "*Red Mine*" of Silverdale and Apedale, next in descending order, lies upon a seam of coal two feet thick; the ironstone measure is variable in thickness, the average of which may be taken as 14 inches.

The "*Bassy Mine,*" also called "*Red Mine,*" is a measure well developed in the eastern part of the coal-field, where it has been extensively wrought. This measure at Shelton has a thickness of 30 inches, and is calcined in large heaps of 2,000 tons, parts of another measure called the "Cannel Row" being used in certain proportions to assist in the calcination. At the

* "Iron Ores of Great Britain," Part iv., pp. 272–3.

Lane End Iron Works these "black band" measures, that is the "Red Shag" and "Red Mine," are employed in about equal proportions with argillaceous ironstone, chiefly the "*Pennystone*," with the addition of some hæmatite from the west coast, in the manufacture of pig iron.

The Cannel Mine next occurs; at Apedale it is described as a black dull compact ironstone, with a fracture slightly conchoidal, and calc spar sparingly exhibited in the faces of the joints. Six beds of these nodules, together 12 inches thick, occur in a section of five feet six inches, and it is reported to yield about 18 cwts. of ironstone to the square yard.

The "*Gabbin ironstone*" measure, occurring some 20 feet below the Spencroft Coal, is a measure from 13 to 16 inches in thickness, interstratified with partings of shale, and bearing a strong resemblance to the measure of the same name in South Staffordshire.

The "*Cannel Row*" and the "*Pennystone*" measures of Shelton are other important seams, the latter consisting of three bands of an aggregate thickness of 20 inches, the lowest band being from 10 to 12 inches in thickness, consisting of a brown stripy coarse-grained stone, with occasional laminæ of black shale, and containing broken fossil remains, and occasional crystalline portions of zinc blende.

The "*Deep Mine*" and "*Chalky Mine*" at Lane End: the former consisting of three bands, and generally regarded as the richest measure of the district, yielding 10 cwts. per square yard; while the latter, 12 inches in thickness in four bands, yields an average of 12 cwts. of ironstone per square yard. A few other ironstone measures occur in depth, notably the New Mine, Little Mine, and Brownstone, capable of producing from 10 to 12 cwts. to the yard. Fish remains are found in quantity in the associated shales of these measures.

The Cheadle Coal-field.—This coal-field is of comparatively small area, its breadth from east to west being about four miles, while its length from Ipstones to Mobberley has a range of five miles. The coal-field is but slightly productive, being composed of only the lower strata of the formation. Near the town of Cheadle the following seams are worked:—

Two-yard Coal.	*Littley Coal.*
Half-yard Coal.	*Four-foot Coal.*
Yard Coal.	*Woodhead Coal*, 3 ft. thick.

These seams crop out towards the north, west, and east, making a sort of trough, and they ultimately pass below the new red sandstone, between Dilhorne and Mobberley towards the south. To the north of the coal-field rise the high moorlands of the millstone grit; and the strata which immediately overlie this formation are finely opened up by the deep channel of the river Churnet. The coal measures reposing on the millstone grit give a thickness of about 370 yards, in which at intervals occur bands of argillaceous ironstone.

The working of the coal and ironstone in North Staffordshire presents some interesting features, which are thus described. Owing to the high dip of the beds of this coal-field, 14 to 16 inches to the foot, the coal has to be worked by system of pillars 40 feet long by only 10 feet thick, the great inclination not allowing them to be any broader. The mode of working adopted is thus explained. The main level or "horse road" is driven horizontally with the cleat of the coal, together with an "air head" 10 yards off on the upper side, which is thirled into every 20 yards for ventilation. This air head afterwards takes the return air from the workings to the "up take," and no miner is allowed to enter it. At every 160 yards a bord or break dip (so called from a break situated at the top to allow the full car to pull up the empty one) is driven "up bank" at right angles to the main level, the longest being 110 yards. A smaller bord for air is likewise run up beside this and thirled into every ten yards. On reaching the top, two drifts are put out from each break dip at 10 yards apart, and the air "bratticed" up by canvas for 40 yards, when it is thirled. These drifts from either side meet at 80 yards, and, after thirling again, the narrow pillars (of 40 by 10 yards, as before mentioned) are worked away against the cleat, the air being made to pass along the face of the work. As soon as taking away the pillars above is fairly commenced, the next drift is driven, so that the working of the pillar above is always slightly in advance of that immediately below.

The ironstone, occurring in measures of varying thickness, is worked nearer the surface on the west (well seen at New Chapel), where the dip is inconsiderable. Owing to the thin beds, ponies are used entirely, and the mode of getting the stone to the main levels is one of the most primitive to be seen anywhere. A man loads the ore on a wooden sleigh, which he then drags on his

hands and knees, through a small road, made through the Gob by packing up with stones on each side. The ironstone is worked away in a face of 30 yards by "holing" the shale below, and putting the shot in above.

Analyses of the Coal.—The following analyses of coals raised by the Chatterley Iron Company from their Whitfield Colliery, near Tunstall, are given by Mr. Charles Homer, F.G.S., in his paper on the North Staffordshire Coal-field and the ironstone measures contained therein.* The coal seams examined were as follows:—

Little Row Coal.—Worked at a depth of 781 yds., 2 ft. 9 in. to 3 ft. 3 in. thick, a good household coal, sold chiefly in the London market; is of a fine bright appearance and of first-class quality.

Old Whitfield Coal.—Worked at a depth of 801 yds.; the seam is 3 ft. 9 in. thick; is a good blast-furnace, steam, and manufacturing coal, and is also in demand for household purposes.

Bowling Alley Coal.—Worked at a depth of 921 yds.; the seam is from 3 ft. 6 in. thick; is a good manufacturing and household coal, and is also used for ironmaking.

Holly Lane Coal.—Worked at a depth of 947 yds., the seam varying from 3 ft. 6 in. to 4 ft. thick; is one of the best household coals in the district, has a good roof and floor, and is cheaply got.

Hard Mine Coal.—Worked at a depth of 948 yds.; it varies from 3 ft. 6 in. to 4 ft. 6 in. thick, and takes its name from its extreme hardness, and from the analysis it will be seen that it is the best coal in the district for blast-furnace purposes, for which it is solely used, and in great demand. It is also a first-class locomotive coal.

RESULTS TABULATED.

Constituents.	Little Row.	Old Whitfield.	Bowling Alley.	Holly Lane.	Hard Mine.
Fixed carbon	61·59	61·27	63·13	61·79	63·50
Volatile hydro-carbon	37·40	37·61	31·70	37·35	34·85
Sulphur	0·20	0·12	0·62	0·06	0·00
Ash	0·81	1·00	4·55	0·80	1·65
Total	100·00	100·00	100·00	100·00	100·00

Production and Distribution of Coal.—In the year 1856, for the first time, the particulars of the output of the North Staffordshire Collieries are separately distinguished from those of South Staffordshire and Worcestershire; the collieries being grouped in the following districts, numbering 123, and producing an aggregate of 1,295,000 tons:—

* Journal of the Iron and Steel Institute, 1875, p. 340.

NORTH STAFFORDSHIRE.	NUMBER OF COLLIERIES.
Cheadle	16
Longton	23
Hanley	12
Burslem	18
Tunstall	15
Biddulph	12
Newcastle-under-Lyme	27
Total	123

The number of collieries for a few years shows little variation. In the year 1860 the production amounted to 2,376,500 tons, the distribution of which was as follows:—

DISTRIBUTION.	TONS.
Coal used in iron-works	538,700
,, ,, in the potteries	150,000
,, ,, ,, ordinary local consumption	875,000
Colliery consumption	15,500
Sent out of district	797,300
Total	2,376,500

Following the production of coal in North Staffordshire since 1860, the annexed table gives the number of collieries and their output, and side by side the production of South Staffordshire and East Worcestershire in each of the same years:—

Year.	No. of Collieries.	North Stafford.	South Stafford, and East Worcester.	Total of County.
		Tons.	Tons.	Tons.
1861	128	2,372,500	4,881,250	7,253,750
1862	114	2,537,250	4,985,500	7,522,750
1863	114	2,698,500	5,171,820	7,870,320
1864	117	3,196,500	8,263,351	11,459,851
1865	125	3,495,750	8,705,239	12,200,989
1866	107	3,734,814	8,664,966	12,399,780
1867	117	3,747,814	8,779,509	12,527,323
1868	113	3,545,830	8,748,950	12,294,780
1869	112	3,724,712	8,944,395	12,669,107
1870	108	3,873,562	9,356,500	13,230,062
1871	115	4,250,000	10,031,250	14,281,250
1872	121	*	10,550,000	...
1873	123	3,892,019	9,463,559	13,355,578
1874	156	4,313,096	8,389,343	12,702,439
1875	157	4,456,213	10,251,791	14,708,004
1876	152	4,077,548	10,081,067	14,158,615
1877	143	4,149,975	9,841,191	13,991,166
1878	145	4,072,416	9,130,774	13,203,190
1879	144	4,025,535	9,350,000	13,375,535
1880†	144	4,074,800	9,660,000	13,734,800

* Included in production of Cheshire and Shropshire, giving a total of 6,327,188 tons. Estimated production of North Staffordshire in the year 1872—4,000,000 tons.

† Reports, H.M. Inspectors of Mines, 1880.

The greater part of the coal raised in North Staffordshire is consumed in the numerous industries located in the area; the most important of these are the ironworks, potteries, and brick manufactures; some quantities are sent out of the district by the Trent and Mersey navigation, and the North Staffordshire Railway. In the year 1871 the distribution of coal was as follows:—

DISTRIBUTION OF COAL.	TONS.
Used in iron works	1,825,000
Potteries and brick works	765,000
Other manufactures	525,951
North Staffordshire Railway	241,841
Trent and Mersey Canal	356,964
Local distribution by railway	505,244
Colliery consumption	30,000
Total	4,250,000

Since 1871 the following statement will give the quantities of coal consumed and distributed as stated:—

DISTRIBUTION BY RAILWAY.

Year.	NORTH STAFFORDSHIRE.		TRENT AND MERSEY.	LONDON AND NORTH-WESTERN.
	Exported.	Local.	Local.	Exported.
	Tons.	Tons.	Tons.	Tons.
1872	266,025	556,768	331,930	59,152
1873	472,097	476,454	297,180	83,534
1874	674,924	517,336	271,016	95,070
1875	632,283	558,086	266,869	89,077
1876	739,978	632,547	215,949	73,738
1877	753,141	609,879	265,267	58,645
1878	727,304	472,940	244,157	63,129
1879	891,974	473,765	250,920	73,602
1880	863,704	387,791	288,321	79,595

In each of the same years the coal used in the iron works, brick works, and potteries were as follows, to which is added the coal used for domestic and other local consumption:—

Year.	Iron Works.	Potteries, Brick Works.	Domestic and local use.
	Tons.	Tons.	Tons.
1873	1,376,000	750,000	400,000
1874	1,000,000	950,000	750,000
1875	1,250,000	950,000	650,000
1876	1,050,000	850,000	600,000
1877	1,228,429	750,000	900,000
1878	1,250,000	750,000	900,000
1879	700.000	650,000	838,510
1880	780,000*	670,000*	863,842*

* Estimated quantities.

Following the returns of production and the distribution of coal in North Staffordshire, the year 1875 appears as the one of greatest production, when 4,456,213 tons of coal were raised, the distribution of which is thus accounted for; side by side will be found similar details for the years 1879 and 1880:—

Distribution.	1875.	1879.	1880.
	Tons.	Tons.	Tons.
North Staffordshire Railway, out of District	632,283	891,974	863,704
Local distribution by railway	558,086	473,765	387,791
Local distribution by Trent and Mersey Canal	266,869	250,920	288,321
London and North-Western carried	89,077	73,602	77,595
Great Northern carried	9,898	21,168	13,547
Used at Iron Works, &c.	1,250,000	700,000	780,000
Colliery consumption	50,000	125,596	130,000
Potteries, Brick Works, &c.	950,000	650,000	670,000
Domestic and local consumption	650,000	838,510	863,842
Total	4,456,213	4,025,535	4,074,800

Of the coal raised in 1880 in North Staffordshire, nearly 2,500,000 tons were consumed in the county, the remainder being distributed by railway. Towards the close of 1879 a demand for coal arose in the district: this was met by increased output and better prices, but the demand did not continue beyond March, 1880, when many of the collieries for a time limited their work to three and four days per week.

Prices of Coal and Cost of Production.—The cost of working varies so much in this as in other districts, according to circumstances, that considerable difficulty is met with in arriving at exact information. In the following well-authenticated data appear some general facts bearing on the point.

In the year 1830 the average cost per ton of getting coal and slack at the Apedale Mines was respectively 2*s.* 7*d.* and 1*s.* The royalty gave an average on coals of 1*s.* 0½*d.*, and on slack 4½*d.* The profit on coals amounted to 11½*d.* per ton, and on slack 1½*d.* per ton. Adding to the above the average cost of dead work, 2*s.* 3½*d.* per ton, the average cost per ton of coals in the Apedale Mines amounted to 6*s.* 10*d.*, and of slack 3*s.* 9½*d.* The above prices give the average of seventeen seams of coal in the mines above named.

In the subjoined table appears the thickness of the several

seams, the produce of coal and slack per acre, and the profit per acre.*

Coal Seams.	Thickness.			Produce per Acre.		Profit per Acre.	
				Coal.	Slack.		
	Yds.	Ft.	In.	Tons.	Tons.	£	s.
Peacock Coal	1	2	0	4,840	806	100	16
Spincroft	1	2	0	4,840	806	100	16
Great Roe	2	0	0	5,808	968	169	8
Kennel	2	0	0	5,808	968	169	8
Little Roe	2	1	0	6,637	1,106	304	3
Rusty Mine	3	0	0	8,712	1,452	399	6
Chalky Mine	1	0	0	2,904	484	24	4
Single Four-foot	1	2	0	4,840	806	80	13
Single Five-foot	1	2	0	4,840	806	221	0
Ragman	1	0	6	2,904	484	105	1
One Yard to Seven-foot	2	2	6	8,228	1,371	754	14
Hams	1	2	0	4,840	806	100	16
Ten-foot	3	0	0	8,712	1,452	980	2
Top Two Roe	0	2	0	1,936	322	...	
Bowling Alley	1	2	0	4,840	806	...	
Seven-foot Nabbs	1	2	6	5,280	880	726	0
Eight-foot Nabbs	1	1	6	4,356	726	598	19
Grey Coal	3	0	0	8,712	1,452	...	

The prices of the above coals and slack delivered into boats or waggons varied, coals from 6*s*. 6*d*. to 12*s*., and slack from 3*s*. 6*d*. to 5*s*. per ton.

In the year 1860 the cost of getting coal and bringing it to bank varied, according to the depth of seam worked, from 2*s*. 6*d*. to 4*s*. 6*d*. per ton. The selling price at pit's bank being: common coal, 6*s*. 2*d*. per ton; and best household coal, 9*s*. 2*d*. per ton. The prices in the year 1870 show a slight advance, increased in 1873 by the operation of the Coal Mines Regulation Act. During the three years ending 1880 the average prices of coal and slack in North Staffordshire were as follows, to which are added the highest and lowest prices per ton:—

Prices.	Coal.						Slack.					
	1880.		1879.		1878.		1880.		1879.		1878.	
	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
Average price	8	4	7	8	9	3	3	9	3	6	4	6
Highest ,,	12	6	11	8	12	6	5	6	5	0	5	0
Lowest ,,	6	6	6	0	8	4	2	6	2	6	3	0

* Smith's "Miner's Guide," 1836, pp. 103, 105.

Population employed in Coal and Ironstone Mining.—Not until the year 1874 have we precise information on this subject; in previous years the numbers employed were grouped in the inspection district, including North Staffordshire, Cheshire, and Shropshire, which, according to the census of 1861, numbered 16,427 male coal-miners. Later, in the year 1867 and subsequent years until the passing of the Coal Mines Regulation Act, 1872, the number of male persons employed as computed by the inspector of the district was as follows, to which are added the quantity of coal raised, and the average number of tons per man:*—

Year.	Number of Persons employed.	Tons of Coal raised.	Tons raised per Man.
	Nos.	Tons.	Tons.
1867	21,000	6,000,000	285
1868	21,000	6,000,000	285
1869	21,000	6,200,000	295
1870	21,200	6,500,000	309
1871	21,000	6,500,000	307
1872	27,753	6,327,188	228

Mr. Thomas Wynne, H.M. inspector of this district, states, in his evidence before the select committee on coal already referred to, that the number of persons employed in the last-named year was arrived at under entirely different circumstances to those obtained in previous years. He says, "Previous to the year 1872 we had no power to call for returns, and in 1872 we had the power, and we called for them; and the return has been made even up to so close as the men who repair railway waggons, the carpenters and blacksmiths, and the loaders of the boats, and every person employed in and about the colliery,"† above ground and underground.

In the year 1873 and subsequent years those employed above and below ground are separately given, amounting in 1873 to 23,177 under ground and 7,444 above ground, or a total of 30,621 persons, of whom 10,000 were engaged in ironstone mining, producing, according to the returns of H.M. inspectors, 6,257,468 tons of coal, and 3,000,000 tons of ironstone, in the district of North Staffordshire, Cheshire, and Shropshire.

* Select Committee on Coal, 1873, p. 329, North Staffordshire, Shropshire, and Cheshire district.

† Report, Select Committee on Coal, 1873, p. 211.

Since 1874 the details appear separately for North Staffordshire,* and are as follows:—

Year.	Persons Employed.		Total employed.	Coal raised.	Raised per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	15,606	5,150	20,756	4,486,483	216
1875	14,908	4,687	19,595	4,202,149	215
1876	13,958	4,603	18,561	3,905,066	210
1877	14,005	3,951	17,956	4,191,320	233
1878	13,063	3,845	16,908	4,140,200	245
1879	12,660	3,346	16,006	4,017,045	251
1880	12,307	3,273	15,580	4,074,800	261

The ages of the 16,006 persons employed in the year 1879 are thus distinguished by Mr. Thomas Wynne, the inspector of the district:—

Male persons.	Under Ground.	Above Ground.	Total.
Ages.	Nos.	Nos.	Nos.
From 12 to 13 . .	96	...	96
,, 10 to 13 . . .	...	4	4
,, 13 to 16 . .	946	206	1,152
Above 16	11,618	3,136	14,754
Total all ages .	12,660	3,346	16,006

Resources and probable Duration of the Coal-field.—Sir George Elliot, Bart., to whom, as a member of the Royal Commission, was intrusted the investigation into the quantity of coal available in North Staffordshire, reports as follows: †—"The coal-field consists of one large, and several small outlying districts, all of which are separately considered. The chief physical characteristics bearing on the inquiry are, the steep inclination of the seams in some parts; the great thickness of coal (150 feet divided into numerous seams) the anticlinal axis running through the district, and the great fault which throws the strata down about 1,200 feet."

The principal district has an area of 30,876 acres, and is bounded on the west and south by the new red sandstone and permian rocks, and on the east by the red sandstone and mill-

* Reports, H. M. Inspectors of Mines.

† Report, Coal Commission, vol. i., pp. 26, 27.

stone grit. The area is much disturbed by faults, the dip of the seams varying greatly in different parts. It is further remarked that the above named area of 30,876 acres was arranged in four divisions for purposes of investigation, the aggregate of which appears in the following statement, in which also is given the estimated quantity of coal in each of the outlying districts, available after deducting portions likely to be sacrificed by faults, barriers, and loss in working, at various depths:—

District.	Surface Area.	Not exceeding 1,500 ft. in Depth.	Between 1,500 ft. and 3,000 ft. in Depth.	Between 3,000 ft. and 6,000 ft. in Depth.	Total at all Depths.
	Acres.	Tons.	Tons.	Tons.	Tons.
1, 2, 3, and 4	30,876	1,325,980,007	1,012,361,046	564,928,888	2,903,269,941
Verges . .	10,400	354,330,240	572,824,815	791,933,744	1,815,299,199*
Cheadle . .	11,616	104,524,603	..	..	104,524,603
Wetley. .	1,200	3,062,400	..	..	3,062,400
Goldsitch. .	90	117,450	..	..	117,450
Total .	51,182	1,788,014,700	1,585,185,861	1,356,862,632	4,826,273,593

In the report of the Commission† the total quantities of coal available at all depths are thus rendered; coal to depths not exceeding 4,000 feet, 3,825,488,105 tons, and below 1,000,785,488 tons, making the aggregate of 4,826,273,593 tons.

Taking the production of the year 1870, as given (3,873,562 tons), since which the production has yearly increased, there remain supplies for the next 1,246 years from that date. Deducting the produce of coal during the ten years ending 1879, amounting to 41,110,364 tons, there remained at that date 4,785,163,229 tons to a depth of 9,000 feet. This quantity, taking the average production of the ten years (4,111,036 tons), it is estimated, will furnish supplies to our numerous industries for a period of 1,164 years compared with 1,246 years from the year 1870. While according to the output in the year 1880, amounting to 4,074,800 tons, ample supplies would be stored for 1,174 years hence.

* This quantity includes 96,210,400 tons of coal in the district of the Verges, at depths between 6,000 and 9,000 feet.

† Report, Coal Commission, vol. i., p. ix.

CHAPTER XII.

SOUTH STAFFORDSHIRE AND WORCESTERSHIRE COAL-FIELD.

Description of Coal-field—The South Staffordshire Mines Drainage Association, its Objects—Analyses, Production of Coal-field, and of the Area under the Mines Drainage Act—Yield of Coal Seams per Acre—Distribution of Coal—Prices and Cost of Production—Population employed above and below Ground—Average Output per Man—Resources and probable Duration of Coal-field.

The South Staffordshire and Worcestershire Coal-field.— This coal-field is one of the most important in central England, and differs from all others in the character of the underlying rock, which is Upper Silurian (Wenlock limestone and shale), the millstone grit, or carboniferous limestone, on which the coal usually rests in other coal-fields, being absent here. In other words, the old land surface, on which the flora of the coal measures grew, was an eroded surface of Upper Silurian rocks.

It has been clearly shown by the late Professor J. B. Jukes, in his "Memoir on the South Staffordshire Coal-field," that, whilst the same accumulations were going on in other parts of England, a broad tract of land, extending over Shropshire, Staffordshire, and Warwickshire, was dry land. Consequently the usually associated condition of other coal-fields is here wanting; both the grits and limestones of the carboniferous series being absent, the well-marked isolated Silurian masses of Dudley, Sedgley, and Walsall, rising from beneath the coal measures, and on which they rest.

The coal-field extends from Rugeley in the north, to the Clent Hills in the south, a distance of twenty miles, embracing the important districts of Cannock Chase, Wolverhampton, Bilston, Dudley, Corngreaves, &c., and has an average width of from seven to eight miles, and is bordered by the Bunter Sandstone and Permian Rock, the former having a thickness of 1,200 feet, the latter exceeding 2,000 feet. The coal measures beneath are divided into upper and middle; the upper division consisting of red and mottled clays, red and grey sandstones, and gravel beds,

and having a total thickness of 800 feet, but barren of coal seams. The middle measures, however, contain a thickness of upwards of 500 feet, in which occur six important seams of coal, interstratified with numerous courses of ironstone. The general thickness of these measures is given as follows by Professor Jukes, the thickness of the seams and strata being the average of many sections in the southern district of the coal-field :—

	Ft.
UPPER COAL MEASURES.	
Red and mottled clays, red and gray sandstones and gravel bed	800
MIDDLE COAL MEASURES (1300 ft.)	
1. *Brooch Coal*	4
Strata with ironstone	130
2. *Thick Coal*	30
Strata with Gubbin ironstone	20
3. *Heathen Coal*	4
Strata with ironstone	109
4. *New Mine Coal*	8
Strata with ironstone	16
5. *Fire-clay Coal*	7
Strata	30
6. *Bottom Coal*	12
Strata with several courses of ironstone . . .	140

The above six seams give a total thickness of 65 feet of workable coal, the most important of which is the "Thick Coal," ten yards thick, a source of great wealth to the district of Dudley. This celebrated seam is in the northern part of the coal basin, near Essington and Pelsall, represented by nine distinct seams, divided and separated by 420 feet of sandstone and shales. Each of these seams has its own under-clays, roof, and fossil contents. One interesting feature in this coal-field is the basaltic mass of Rowley Regis, forming a hill two miles in length and 820 feet in height. Professor Jukes * considers that this rock has been poured out in the form of a lava flow during the coal period, for the beds of coal dip under the basalt, and have been followed and found "blackened" or charred, and utterly worthless.†

The flooded condition of the collieries in and around Bilston renders the enormous quantity of 150,000,000 tons of coal unworkable. To provide a remedy, and to make this great mass of coal, and the ironstone measures associated with it, more easily available, the "South Staffordshire Mines Drainage Act, 1873,"

* For detailed information of the "South Staffordshire Coal Field," see "Memoirs of the Geological Survey," by J. Beete Jukes, F.R.S. Second edition, published 1859.

† This coal has of late years been used in several manufactures, also on railways. It is not charred, but converted into a black pulverulent mass.

was passed, the works of which are now in active operation. This flooding or ponding up of water in the mines has been occasioned by a great part of the drainage area having subsided, causing hollows, which, often occurring in the water courses, find their way into the mines below, and become a fruitful source of danger to life and property.

The geological or under-ground configuration of the drainage area may be described as a series of basins, separated by faults, and in each basin the strata incline more or less to the centre of the basin, at which they come at their lowest point. The result is that all mines in any one of these basins are dependent upon each other, and (except so far as surface percolation is concerned) independent of other basins. Consequently the mines on the top edge of a basin are little troubled with water, their water naturally draining into the mines of their less fortunate neighbours lower down.

In carrying the Act into operation, the Commissioners had three important things to consider. First, to subdivide the drainage area into districts, following the natural configuration of the strata, so that each district might consist of a subterranean basin, and, so far as its underground drainage was concerned, be entirely unaffected by, and unable itself to affect, any other district. In the second place, it was necessary to introduce an efficient system of surface drainage to prevent water percolating from surface water-courses and drains into the mines; and thirdly, an efficient system of underground or mine drainage, by removing the water which is actually in the strata itself. The mines in the area are classified under the following heads :—

(1.) Mines at the top edge of an underground basin (" called mines in the cross"), which are necessarily free from water;
(2.) Mines obstructed and requiring perpetual pumping;
(3.) Flooded mines; and
(4.) Exhausted mines.

The necessary funds for carrying out the Act are provided by two distinct rates—the one called the " General Drainage Rate," applicable for the purposes of surface drainage; the other, the "Mines Drainage Rate," applicable for the purposes of underground drainage.

The engineering works of this comprehensive scheme have

been carried out under the able superintendence of commissioners, assisted by Mr. E. B. Marten, C.E., of Stourbridge; and an instructive model on a large scale of the area of the country included in the Act, constructed by Mr. James B. Jordan, and deposited in the offices of the commissioners at Wolverhampton, illustrates the configuration of the country and the details of the scheme.

Analyses of the Coal.—The Ten Yard, or "Thick Coal," from the Whyley Colliery, and the "Heathen Coal," two important seams in the South Staffordshire and Worcestershire coal-field, are thus referred to by Dr. Percy: * "Non-caking coals, rich in oxygen; the Ten Yard or Thick Coal, from the Whyley Colliery, in the vicinity of West Bromwich, this seam consists of ten or more beds, to which special names are applied, viz., 'Rooves,' 'Top Slipper,' 'White Coal,' and 'Brazils;' the last-named contains much earthy matter, and is in request for certain reverberatory smelting furnaces in Birmingham." The powder of each of these coals is brownish-black.

The Heathen Coal, from the Grace Mary Colliery, Rowley Regis.—"This seam is between 5 and 6 feet thick, lies at the depth of a few yards below the Ten Yard Coal, and is overlaid by the Gubbin ironstone. The coal is bright black, non-caking, and yields a buff-coloured ash."

The composition of these coals appears in the annexed table:—

Composition exclusive of Water.	TEN YARD OR THICK COAL.				Heathen Coal.
	Rooves.	Top Slipper.	White Coal.	Brazils.	
Carbon	76·12	77·01	76·40	72·13	70·41
Hydrogen	4·83	4·71	4·62	4·32	4·69
Oxygen	16·72	16·72	17·43	17·11	12·47
Sulphur	1·00	0·74	0·55	0·54	0·71
Ash	2·33	1·56	1·55	6·44	2·20
Water	...	...	...	...	9·52
Total	101·00	100·74	100·55	100·55	100·00
Composition exclusive of Sulphur, Ash, and Water.					
Carbon	78·46	78·53	77·68	77·33	80·41
Hydrogen	4·96	4·80	4·69	4·67	5·35
Oxygen and Nitrogen	16·58	16·67	17·63	18·00	14·24
Total	100·00	100·00	100·00	100·00	100·00

* Percy's "Metallurgy," Fuel, p. 325.

Other seams, worked at Grace Mary Colliery, Rowley Regis, are thus described: * Sawyer Coal.—"This coal forms one of the constituent seams of the Ten Yard or Thick Coal; the sample analysis came from the neighbourhood of an igneous dyke. Coke, slightly coherent, moderately lustrous; flame, yellow, smoky; colour of the ash, buff." Brazils Coal.—"This also forms part of the Thick Coal, and, like the last sample, came from the neighbourhood of an igneous dyke. Coke, slightly coherent, moderately lustrous. Flame, yellow, smoky. Colour of the ash, buff." These analyses were made in Dr. Percy's laboratory, in the Royal School of Mines, by Mr. Charles Law, and give the following results:—

RESULTS TABULATED.

Constituents.	Sawyer Seam.	Brazils Seam.
Carbon	68·40	67·34
Hgdrogen	4·43	4·62
Oxygen and Nitrogen .	10·28	11·68
Sulphur	1·05	0·62
Ash	8·91	8·00
Water	6·93	7·74
	100·00	100·00

The composition per cent., exclusive of sulphur, ash, and water, being:—

Constituents.	Sawyer.	Brazils.
Carbon	82·30	80·51
Hydrogen	5·33	5·52
Oxygen and Nitrogen .	12·37	13·97
	100·00	100·00
Yield of Coke . .	64·00	60·70

Production of Coal.—It appears, from Plott's History of Staffordshire, that in the year 1785 there were twelve collieries at work in the coal-field, in the districts of Wednesbury, Dudley, and Sedgley, and twice as many out of work, some of which afforded 2,000 tons yearly, others three, four, or five thousand tons per annum. From which it may be estimated that the production of coal at this period, in these important districts, did not exceed

* Percy's "Metallurgy," Fuel, p. 569.

50,000 tons. In the year 1800 a committee was appointed by Parliament to inquire into the inland coal trade. From the evidence bearing on Staffordshire, it is stated by Mr. Alexander Rabey, an iron merchant,* that "the present price of the Staffordshire (coal) at the pit is six shillings per ton, of 21 cwts., and 120 lbs. to the cwt.; inferior coals are sold at three shillings per ton; the small coal for engines are from one shilling to one shilling and sixpence per ton." Mr. Rabey does not give any facts bearing on production or distribution, but he gives the following information, showing the price of coals after the cost of conveyance has been added :—

"I compute the average distance of those collieries (the Dudley collieries), to Brentford, 148 miles; the boatage, ¾*d.* per ton per mile; 9*s.* 3*d.* boy and horse, of back carriage included, would be about ½*d.* per ton per mile, is 6½*d.* more, in all, about £1 1*s.* 5*d.* per ton." A London chaldron of the Newcastle coals will be about twenty-seven cwts.; he adds one-third of the weight and one-third of the price on a London chaldron. Therefore, if Staffordshire coals to Brentford cost £1 8*s.* 7*d.* per chaldron, allowing 2*s.* 11*d.*, they would stand, when imported into London, about 33*s.* per ton.

Returning to the coal production of Staffordshire, we have it, on the authority of Samuel Salt, for the year 1816, that it amounted to 795,000 tons. The same gentleman, in his "Statistics and Calculations," gives the total output of the collieries of Great Britain for the same year (1816) as 27,020,115 tons.

Since the year 1854, ample information has been published, showing the number of collieries working in the South Staffordshire coal-field, including that portion of the coal-field in the county of Worcester, in the neighbourhood of Dudley. The number of collieries at full work at this period was 500, which had at least 2,000 pits, and of these a large majority produced nearly 100 tons of coal per week. The total production of coal in North and South Staffordshire at this period was 7,500,000 tons, the quantities carried out of the county being comparatively small, the pig iron industries consuming 3,415,200 tons.

The number of collieries, and the annual output from 1854 to 1863, are as follows :—

* Inland Coal Trade, "Report of the Committee, 1800," Evidence on Staffordshire.

Year.	Collieries.	Production of Coal.	Year.	Collieries.	Production of Coal.
	No	Tons.		No.	Tons.
1854	393	*7,500,000	1859	422	4,450,000
1855	377	*7,323,000	1860	441	5,271,800
1856	425	6,010,500	1861	452	4,881,250
1857	438	5,509,625	1862	457	4,985,500
1858	424	4,955,780	1863	465	5,171,820

Since the year 1864 two sources of information are at hand, giving the output of the collieries in South Staffordshire and Worcestershire; the one from the "Mineral Statistics of the United Kingdom," the other from the "Annual Reports of Her Majesty's Inspectors of Coal Mines." The collieries of this district, it may be observed, are very numerous; many of them, however, are but small workings. It not unfrequently happens that a pit is opened and, a few tons of coal having been obtained, it is closed within a few months. The following table shows the number of collieries in each year, the variation in numbers being due to the cause above referred to, as well as pits being included as collieries, also the respective quantities of coal raised as determined by the Keeper of Mining Records in each year.

Year.	Collieries.	Mineral Statistics.	Year.	Collieries.	Mineral Statistics.
	No.	Tons.		No.	Tons.
1863	465	5,171,820	1872	319	10,550,000
1864	523	8,263,351	1873	407	9,463,559
1865	542	8,705,239	1874	469	8,389,343
1866	512	8,664,966	1875	442	10,251,791
1867	572	8,779,509	1876	434	10,081,067
1868	†327	8,748,950	1877	457	9,841,191
1869	326	8,944,395	1878	437	9,130,774
1870	326	9,356,500	1879	425	9,350,000
1871	307	10,031,250	1880	413	‡9,660,000

Bearing on the question of production in South Staffordshire, it may be noted that the coal deposits of Cannock Chase are now (June, 1881) in course of rapid development, one company producing on an average 2,000 tons per day, and even more; and should occasion require, the same company is in a position to increase its output to 3,000 tons daily. Recently, at one of the pits of the Cannock and Rugeley Company, 1,051 tons were brought to bank from a depth of 350 yards in a period of eight hours.

The Keeper of Mining Records, referring to the returns for the

* Including the production of North Staffordshire.

† In previous years pits were included as collieries.

‡ Report of H.M. Inspectors of Coal Mines.

year 1864, remarks *: "It will be necessary to make corrections in former years, all the returns being too small. This has arisen from my having taken the 'boat load' as being 20 tons." The best explanation of the difficulty will be given in the following paragraph from a paper read at a conference of mine owners and agents, by Rupert Kettle, Esq., Vice-President of the Dudley and Midland Geological Society:—

"We have in one colliery district three different weights, each called and commonly recognized as a ton. First, the statutable ton, that is, the avoirdupois weight of 2,240 lbs. Next, we have the long hundred, or long weight, as we commonly understand it, that is, 120 lbs. to the hundred-weight instead of 112 lbs., giving 2,400 lbs. to the ton. And then, thirdly, we have the 'boat load' of 24 long hundreds, or 2,880 lbs. to the ton: and, lastly, there is a measure acted upon, I am sorry to say for business purposes, called a 'boat load.' I should very much like some one to tell me any rule by which I can ascertain the exact weight, according to the law standard, of the whole, or any aliquot part of a 'boat load' of coals. I know a boat load is 20 tons, and the furthest to which I can carry the weight is 20 tons 'lease weight,' that is 57,600 lbs. or 25 tons, 13 cwts., 2 qrs., and 16 lbs. weight, and yet I am told that sometimes a 'boat load of coals' will what is called weigh out thirty hundred-weight to the ton."

In considering the production of coal, and the area of this coal-field included under the operation of the "South Staffordshire Mines Drainage Act, 1873," the importance of the work will be understood by the returns of the several districts of coal produced, upon which rates were levied in each year since 1874. It must be remembered, however, that the largest part of the coal obtained annually in South Staffordshire is worked outside the Mine's Drainage area:—

Districts.	1874.	1875.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.
Tipton . .	1,103,396	950,666	584,075	434,798	518,602
Bilston . .	640,926	568,687	242,637	175,420	204,531
Kingswinford.	757,937	835,561	724,530	709,315	696,658
Old Hill . .	782,193	884,127	699,784	684,522	828,430
Oldbury. .	641,103	867,728	904,748	946,966	940,813
Total .	3,925,555	4,106,769	3,155,774	2,951,021	3,189,034

* Mineral Statistics, 1864, p. 90.

The yield per acre of the seams of coal is a matter of great importance, varying considerably in this district, more particularly in the "Ten Yard Coal," the thickness of which, exclusive of its partings of clay and shale, averages 8 yards, 2 feet, 3 inches. The following table, by Mr. Thomas Smith, gives practically the average quantities of coals, lumps, and slack obtained from each acre of coal, of the thickness indicated:—*

Coal Seams.	Thickness. Yds.	Ft.	In.	Coals. Tons.	Lumps. Tons.	Slack. Tons.
Brooch Coal	1	0	9	1,815	363	1,452
Flying Reed	1	1	0	3,226	645	968
Thick Coal	8	2	3	10,400	1,733	3,267
Heathen Coal	1	0	0	2,420	484	726
New Mine Top and Bottom Coal	4	2	6	11,695	2,339	3,508
New Mine Bottom Coal	3	2	6	9,275	1,855	2,782
Total thickness	21	0	0			
Total quantities, the Thick Coal being got with ribs and pillars				38,831	7,419	12,703
Additional if the Thick Coal be got by long work				10,574	2,494	3,025
Total quantities if got by long work				49,405	9,913	15,728

Distribution of Coal.—The London and North Western Railway carried, in the year 1859, out of South Staffordshire, 94,000 tons of coal, the total quantities carried by the same railway system in the year amounting to 2,721,000 tons. In the years 1860 and 1861 the production is thus accounted for:—

How Distributed.	1860. Tons.	1861. Tons.
Used at Iron Works	2,975,000	2,550,500
Used in Collieries and Lime Works	156,800	160,750
Local consumption	650,000	650,000
Sent out of district	490,000	1,520,000
Total	4,271,800	4,881,250

Ten years later the following details of distribution appear for the years 1870 and 1871:—

* Thomas Smith's "Miners' Guide, 1836," p. 79.

How Distributed.	1870.	1871.
	Tons.	Tons.
Used at Iron Works	3,185,750	3,585,750
Used in other manufactures . .	1,350,000	1,500,000
Domestic consumption	1,850,000	1,875,500
Colliery " , &c. . .	1,250,750	1,350,000
By Railway and Canal . . .	1,720,000	1,720,000
Total . .	9,356,500	10,031,250

The annexed table shows the quantities of coal used at the ironworks, and sent out of the district by railway:—

Year.	Iron Works.	London and North Western.	Midland.
	Tons.	Tons.	Tons.
1860	2,975,000	93,000	60,104
1861	2,550,500	...	89,048
1862	2,350,500	211,210	88,248
1863	2,561,320	314,695	79,809
1864	4,660,945	389,174	85,922
1865	4,655,940	314,121	...
1866	4,588,375	272,892	33,376
1867	3,979,379	337,417	43,263
1868	3,293,450	455,967	34,667
1869	3,170,500	626,308	41,189
1870	3,185,750	665,720	42,305
1871	3,585,750	708,597	47,660
1872	*3,250,000	809,622	53,842

In the last-named year the Great Western Railway carried 494,608 tons out of South Staffordshire, and 408,219 tons from the Ruabon district into the same county. Following the distribution of coal, the annexed statement gives the details for the year 1880 and the three previous years:—

How Distributed.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.
Carried out of County by London and North-Western Railway	1,138,293	1,086,370	1,499,337	1,511,099
Carried out of County by Midland Railway	163,903	169,392	209,561	189,247
Carried out of County by the Great Western	344,702	325,364	311,178	306,141
Carried by Birmingham Canal for Birmingham	916,288	859,122	828,942	770,245
Carried by Birmingham Canal for Works in Mining Districts .	3,144,460	3,030,570	2,968,800	3,401,613
Carried out of County by ditto Canal	207,995	208,828	227,782	214,390
Domestic Consumption, in addition to Birmingham	1,775,550	1,801,128	1,500,180	1,440,265*
Colliery Consumption, &c.. . .	1,255,000	1,000,000	950,110	965,000*
Used in Manufactures, extra . .	895,000	650,000	854,110	862,000*
Total produce of South Staffordshire and Worcestershire	9,841,191	9,130,774	9,350,000	9,660,000

* Estimated quantities.

Before considering the distribution of coal by canal, it will be desirable to trace generally the distribution by railway since the last returns for the year 1872. It will be useful at the same time to record the quantities of coal brought into South Staffordshire by the Great Western Railway from the Ruabon district:—

Year.	London and North Western.	Midland.	Great Western.	
			Out of South Stafford.	From Ruabon.
	Tons.	Tons.	Tons.	Tons.
1873	971,525	106,484	487,635	397,069
1874	632,630	60,590	303,187	347,527
1875	1,161,425	140,593	398,842	369,084
1876	1,203,401	181,511	369,102	352,777
1877	1,138,293	163,903	344,702	294,316
1878	1,086,370	169,892	325,364	263,268
1879	1,499,337	209,561	311,178	250,953
1880	1,511,099	189,247	1,511,099	285,850

The other items of distribution in each of the same years, attracting attention, are the quantities conveyed by the Birmingham Canal to the various works in the mining districts in South Staffordshire, and for domestic consumption.

Year.	To Birmingham.	To Mining Districts.	Domestic Consumption.	Collieries Consumption.
	Tons.	Tons.	Tons.	Tons.
1873	812,668	3,500,223	1,750,000	1,300,000
1874	776,881	3,114,305	1,750,000	1,525,000
1875	939,779	3,377,355	1,675,500	1,279,000
1876	936,724	3,114,821	1,650,000	1,250,000
1877	916,288	3,144,460	1,575,550	1,255,000
1878	859,122	3,030,570	1,801,128	1,000,000
1879	828,942	2,968,800	1,500,180	950,110
1880	770,245	3,401,613	1,440,265	965,000

The distribution of coal is greatly facilitated in South Staffordshire by the system of water communication traversing the county in all directions; and the Birmingham Canal Navigation, which has direct communication with the adjoining counties of Worcester and Warwick. The annexed table will show the quantities of coal sent by the several canals carrying from South Staffordshire in each of the years named:—

Year.	Worcester Canal.	Warwick Canal.	Coventry Canal.	Staffordshire and Worcestershire Canal.	Whittington to Fazeley.
	Tons.	Tons.	Tons.	Tons.	Tons.
1866	135,585	77,205	518	13,776	1,039
1867	148,000	94,165	2,149	19,661	3,044
1868	148,186	98,248	1,778	28,317	4,772
1869	148,474	104,021	1,210	41,724	2,946
1870	140,453	103,286	773	48,502	2,812
1871	127,859	110,243	322	52,845	2,395
1872	118,779	91,374	340	59,132	1,160
1873	118,672	90,087	452	64,650	847
1874	102,130	67,785	405	55,951	479
1875	117,552	25,626	213	83,660	902
1876	116,061	9,534	405	97,555	1,972
1877	112,051	7,685	572	85,301	2,385
1878	110,176	6,834	2,373	83,755	5,689
1879	116,058	23,459	206	83,946	4,112
1880	109,909	15,269	612	87,186	1,415

Supplementing the above quantities with the tonnages of coal sent to Birmingham, and carried for the supply of works in the mining districts, by the Birmingham Canal Navigation, the following totals show the aggregate distribution of coal by canal in each of the years named :—

BIRMINGHAM CANAL NAVIGATION.

Year.	Coal carried.	Year.	Coal carried.
	Tons.		Tons.
1866	3,601,621	1873	4,587,600
1867	3,841,062	1874	4,117,937
1868	3,786,369	1875	4,545,089
1869	4,302,103	1876	4,277,054
1870	4,312,582	1877	4,268,744
1871	4,415,697	1878	4,098,521
1872	4,495,333	1879	4,025,525

The quantity carried in 1880 amounted to 4,386,248 tons.

Prices of Coal and Cost of Production.—In 1836 Mr. Thos. Smith, in his "Miners' Guide," gives the following quotations per ton of coals of different descriptions delivered into boats or waggons at the pits, the coals quoted being raised at the Deepfield Mine :—

DEEPFIELD MINE.

		s.	d.
Brooch Coal, large	. . . .	8	0
,, lumps	. . . .	5	0
,, rakings	. . . .	3	9

DEEPFIELD MINE (*continued.*)

	s.	d.
Brooch Coal, slack	2	6
,, coke, per sack	1	4
Thick Coal, best	9	0
,, second	8	0
,, inferior	7	0
,, furnace coal	6	6
,, lumps	5	0
,, slack, good	2	9
,, ,, small	2	6
New Mine Top and Fire-clay Coals, best	7	0
,, ,, ,, furnace coal	6	0
,, ,, ,, lumps	5	0
,, ,, ,, rakings	3	6
,, ,, ,, slack, good	2	9
,, ,, ,, ,, inferior	2	6
New Mine, bottom coal, best	6	0
,, lumps	4	6
,, slack	2	6

The above are the actual charges at the time, but the prices of all the varieties of coal vary considerably, according to their quality, which is by no means the same in all parts of the same district or collieries.*

The average cost per ton of getting coals, lumps, and slack from the various coal seams was as follows at the period above referred to:—

Coal Seam.	Coal.		Lumps.		Slack.	
	s.	d.	s.	d.	s.	d.
Brooch	4	3	1	2	1	0
Flying Reed	2	6½	1	2	1	0
Thick Coal	2	4	1	2	1	0
Heathen Coal	2	7	1	2	1	0
New Mine Top and Fire Clay Coal	1	10½	1	2	1	0
New Mine Bottom Coal	1	10½	1	2	1	0
Total	15	5½	7	0	6	0

The average price per ton of these six seams of coal being, coals, 2*s*. 7*d*.; lumps, 1*s*. 2*d*., and slack, 1*s*.

When in 1873 a great demand for coal arose, due to the general activity of trade, prices increased considerably, varying from 15*s*. to 19*s*. per ton; prices in the previous year ranging from 11*s*. 3*d*. to 15*s*. per ton. Mr. Fisher Smith, in his evidence

* "Miners' Guide," Thomas Smith, p. 84.

before the Select Committee on Coals,* states that upwards of 1,000,000 tons of coal are raised in the year from the collieries belonging to the Earl of Dudley, nearly one-half of which is used in iron manufacture, and in the production of which from 8,000 to 10,000 men are employed. It further appears that hewers' wages in 1873 were 5*s.* 6*d.* per day for less hours' work than in the year 1869, when wages varied from 4*s.* to 4*s.* 6*d.* per day. To illustrate this more clearly one pit is taken as a fair average, in which the hewers made in the week 7·3 days, for which they received 29*s.* 3*d.* In 1872 they did 7·2 days, earning £1 15*s.* 7*d.* per week, and in 1873, in 7·3 days, earning £2 0*s.* 5*d.* per week, the above rates being an average of 10 men for each period, some of the highest and some of the lowest. In 1869 they worked 11 hours per day, diminished to 8 hours in 1872 and 1873.

Immediately preceding the passing of the "Coal Mines Regulation Act, 1872," the prices of thick coal, at the respective collieries of the Earl of Dudley, were as follows:—

Coal	13*s.* per ton.
Lumps	12*s.* ,,
Slack (engine)	6*s.* ,,

The effect of the Act in the district has been to increase the cost of coal something like 1*s.* per ton.

The wages of colliers in South Staffordshire have not undergone such great fluctuations during the past ten years as in most other coal-fields. Between 1870 and 1873 they rose from 40 to 45 per cent.; but a good deal of it was in the form of the reduction of the hours of work. In South Staffordshire the hours of labour fell from sixty-six a week in 1871 to forty-eight in 1873, while the wages rose from 5*s.* a day to 5*s.* 6*d.*; that is, the hours of work decreased 29 per cent., and wages increased 10 per cent., making altogether an advance of nearly 40 per cent. In North Staffordshire the hours of labour also fell from 58 to 50 per week, and wages were advanced 30 per cent. Since then the reverse movement has taken place. The wages are now regulated by a sliding scale, according to the selling price of coal.†

The present selling prices of coal per ton of 2,240 lbs., from

* Report, Coal, 1873, p. 91.

† "Ten Years' Coal Mining, Staffordshire," *Colliery Guardian*, vol. xl., 1880, p. 492.

the Earl of Dudley's collieries, are as follows (September, 1881), these prices have been current for upwards of nine months :—

EAST OF DUDLEY (TIPTON DISTRICT).

THICK COAL.

	INTO BOATS. s.	d.
Best (Household)	9	0
Furnace	8	0
Forge or Steam	8	0
Engine Slack (Best)	4	0
Fine Slack (Ordinary)	3	6
NEW MINE COAL.		
Large	9	0
Forge	8	6
Engine Slack	4	6
HEATHEN COAL.		
Large	9	0
Forge	8	6
Engine Slack	4	6

WEST OF DUDLEY (BRIERLEY HILL DISTRICT).

THICK COAL.

	s.	d.
1. Best (Household)	12	0
2. Furnace	8	6
3. Steam (For locomotives)	7	0
4. Screenings (Bright)	7	0
5. Screenings (Steam)	6	6
6. Engine Slack (Best Himley Colliery)	4	0
7. Engine Slack (Ordinary)	3	6

In the beginning of February, probably due to the severe weather previously prevailing, the quotations of coal and slack were advanced, making furnace coal, 10*s.* per ton; forge coal, 8*s.* 6*d.*, and engine coal and slack, 5*s.* per ton. These quotations, regulating the basis of the coal trade in Staffordshire, will accordingly lead to an advance of wages of 3*d.* per day to men working on thick coal, and 1½*d.* to the men employed in the thin coal seams. No change appears to have been made in the Cannock Chase district, where the Cannock Chase Railway Collieries Company, one of the leading firms, give the following quotations: best deep coal, 10*s.*; yard coal and best deep cobbles, 9*s.*; shallows, 8*s.* 6*d.*; steam çoal, 6*s.* 6*d.*, and slack, 6*s.* 6*d.* and 5*s.* 6*d.*, according to quality.

Population employed above and below Ground.—In the working of coal and ironstone in Staffordshire, in the year 1854,

there were employed in coal mining 25,681 persons of all ages, and in ironstone mining 2,870 persons; these totals include all employed above and below ground. In the Worcestershire extension of the coal-field 2,188 persons were employed in the same year in coal-mining, and 252 in ironstone mining, giving an aggregate of 27,869 persons in coal mining, and 3,122 persons in ironstone mining. The census of the year 1861 gave 25,235 persons as the number employed in South Staffordshire and Worcestershire; increased in the year 1864 to 26,620 persons, when the production of the coal-field was, according to the returns of Her Majesty's Inspectors of Collieries, 10,206,000 tons of coal, giving an average annual yield per man of 383 tons.

In subsequent years we have the following numbers of persons employed computed by the inspector of the district, to which is added the output of coal, and the average yield per man:—

Year.	Persons Employed.	Coal Raised.	Average per Man.
	No.	Tons.	Tons.
1864	26,620	10,206,000	383
1865	27,000	10,201,000	380
1866	27,000	10,300,000	381
1867	27,100	10,268,000	379
1868	28,000	9,900,000	350
1869	28,500	10,408,000	365
1870	29,000	10,400,000	358
1871	31,000	10,500,000	338
1872	31,500	10,550,000	335

These returns exhibit a gradual decline between the years 1864 and 1872 in the average output per man of 48 tons, equivalent to a decrease of 12 per cent.

In the year 1873, under the provisions of the Coal Mines Regulation Act, the total number of persons employed in South Staffordshire, in coal and ironstone mining, was 36,829, of whom 27,497 were engaged under ground, and 9,932 above ground. Since that date, the number of persons employed, and the quantity of coal and ironstone raised in South Staffordshire and Worcestershire, has been as follows; * to which is appended the average yield per man in tons:—

* Reports of H.M. Inspectors of Mines.

Year.	PERSONS EMPLOYED.			Coal Raised.	Ironstone. Raised.	Average per Man.
	Under.	Above.	Total.			
	Nos.	Nos.	Nos.	Tons.	Tons.	Tons.
1873	27,497	9,332	36,829	11,100,000	346,644	310
1874	27,304	9,551	36,855	8,500,000	246,174	237
1875	26,457	9,211	35,668	10,300,000	384,055	299
1876	24,476	8,322	32,798	10,000,000	294,482	313
1877	21,483	7,277	28,760	9,500,030	206,452	337
1878	18,681	6,422	25,103	8,976,000	191,513	365
1879	17,641	5,914	23,555	9,329,197	149,204	402
1880	17,563	5,930	23,493	9,660,000	186,245	423

In the year 1879, the numbers of persons employed in the South Staffordshire and Worcestershire parts of the coal-field are given separately, and appear as follows:—

Districts.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
South Staffordshire .	15,045	5,061	20,106
Worcestershire . .	2,596	853	3,449
Total .	17,641	5,914	23,555

Their respective ages being thus distinguished:—

Male Persons.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
From 12 to 13 . . .	21	...	21
" 10 to 13 . . .	...	3	3
" 13 to 16 . . .	1,256	368	1,624
" 13 to 16 . . .	...	89*	89
Above 16	16,364	5,057	21,421
" 16	...	397†	397
Total .	17,641	5,914	23,555

In examining the average quantity of coal and ironstone raised per man in South Staffordshire, according to the returns of Her Majesty's Inspectors, a great falling off appears in the year 1874, when it did not exceed 237 tons; the diminished output arose from a "strike," which prevailed for about four months. This, with the depressed condition of the iron trade, on which

* Females, 18 in Staffordshire and 71 in Worcestershire.

† Females, 316 in Staffordshire and 81 in Worcestershire.

the consumption of coal greatly depends, reduced the output from 11,100,000 tons in 1873 to 8,500,000 tons the following year, a decrease of 2,600,000 tons, equal to 23 per cent. Since 1874 the average output has steadily increased, and results in this direction compare favourably with other coal producing districts.

Comparing the results of the past ten years with the average yield per man in the year 1835, we have the following as the actual quantity of coal and ironstone got per man per day in the South Staffordshire coal-field, from the seams named :—*

Coal Seams.	Coals.			Lumps.			Slack.		
	Tons.	Cwts.	Qrs.	Tons.	Cwts.	Qrs.	Tons.	Cwts.	Qrs.
Brooch Coal . . .	1	4	0	0	5	0	1	0	0
Flying Reed Coal . .	2	10	0	0	10	0	0	15	0
Thick Coal . . .	5	0	0	1	0	0	1	10	0
Heathen Coal . . .	2	3	0	0	9	0	0	13	0
New Mine Top and Fire Clay Coals . . .	3	9	1	0	10	2	1	0	3
New Mine Bottom Coal.	4	10	0	0	18	0	1	7	0
	18	16	1	3	12	2	6	5	3
Average day's getting .	3	2	2	0	12	0	1	0	3

giving a total daily production of 4 tons 15 cwts. 1qr. per man. The output of ironstone, according to the same authority, per man per day being as follows, from the ironstone measures named :—*

Ironstone Measures.	Tons.	Cwts.	Qrs.
Thick Coal or Black Gubbin.	0	18	3
New Mine ,, ...	0	16	2
Poor Robin	0	18	3
White Stone	2	6	0
Balls	0	15	0
Gubbin	0	15	0
Blue Flats	2	6	0
	8	16	0
Average day's getting	1	5	0

Resources of Coal-field and probable Duration.—The result of the Coal Commission Inquiry shows that the aggregate acreage of coal, estimated as remaining unworked in South Staffordshire,

* "Miners' Guide," by Thomas Smith, of Sandy Fields, near Sedgeley, 1836. pp. 82, 83.

East Worcestershire, and Shropshire coal-fields, extend over an area of 136,368 acres, the coal amounting to 2,266,668,310 tons, while 360,548,542 tons are deducted as unavailable through inferior quality, waste in working, or destroyed by faults or other causes, leaving 1,906,119,768 tons available for future use. These estimates do not include any seam less than 12 inches in thickness, nor is any seam known to exist below 500 yards. Assuming 20 millions as the available coal remaining in the Shropshire area, there remained in the year 1870 some 1,886,119,768 tons in the South Staffordshire coal-field, which, at the rate of production (9,356,500 tons) in the year 1870,* would be exhausted in 200 years from that date.

Deducting the coal raised during the ten years ending 1879, amounting to 96,445,475 tons, there remained at the end of 1879 some 1,789,674,293 tons, which, at the average of the past ten years, 9,644,547 tons, would afford supplies for 186 years hence.

The production of this coal-field in the year 1880 shows a slight increase over the average output of the past ten years; the total amounting to 9,660,000 tons, of which 8,231,000 tons was raised in South Staffordshire, and 1,429,000 tons in the Worcestershire extension of the coal-field.

The "ten yard" or thick coal, on either side of Dudley, was estimated by Mr. William Matthews in 1870 to last 40 years from that date, at the then rate of production.

* Mineral Statistics of the United Kingdom.

CHAPTER XIII.

NORTH WALES COAL-FIELDS.

Description of the Anglesea, Denbigh, and Flint Coal-fields and Succession of Strata—Analyses—Production and Distribution of Coal—Population employed in Coal Mining—Resources and probable Duration.

The North Wales Coal Fields.—These are situated in the counties of Anglesea, Denbigh, and Flint. The *Anglesea coal-field* * forms a band of country stretching from Hirdrefaig, to Malldreath Bay, a distance of nine miles, its breadth at Malldreath Marsh being a mile and a half. The succession of strata as determined by Professor Ramsay appears in the following section.†

SUCCESSION OF STRATA ANGLESEA COAL-FIELD.

		Ft.	In.
Permian Rocks.—Red Sandstone, Marl and conglomerate		195	0
Coal Measures (1309 ft.).—Coal (Glopux) lying in lumps		9	0
	Shale	51	0
	Coal	3	0
	Shale	63	0
	Coal	4	0
	Strata	75	0
	Coal (irregular)	2	0
	Strata	43	0
	Coal	6	0
	Strata	90	0
	Coal (with Cannel roof)	1	8
	Strata (about)	300	0
	Coal (supposed Berw Uchaf coal, in three beds with partings	7	6
	Strata	650	0
Millstone Grit.—Coal (perhaps in Millstone Grit) 2 ft. 0 in.		to 3	0
,, ,, Yellow Sandstone and conglomerate		200	0
Carboniferous Limestone.—Grey and Black Limestone and Sandstone with Productus, Spirifer, Corals, &c.		450	0

There are eight seams of coal in this outlying coal-field, from which no coal was raised in the year 1879 or 1880.

The Denbighshire Coal-field is some eighteen miles in length by four in width, commencing three miles south of Oswestry,

* "Coal-fields of Great Britain," pp. 162, 163.

† "Explanation of Section of Geological Survey," sheet 40, and Geological Map, sheet 78.

where the new red sandstone begins to rest directly on the Millstone Grit, and extends northward by Oswestry to Ruabon and Wrexham, to the north of the valley of the Alyn. The seams of coal in the field are not numerous, nine in number. The upper and lower sulphurous seams at the top of the series are not worked. The other seams and strata occur in the following order with the respective thicknesses :—

SUCCESSION OF COAL SEAMS, DENBIGHSHIRE COAL FIELD.

	Yds.	Ft.	In.
Top Sulphurous Coal	0	4	0
Strata	70	0	10
Bottom Sulphurous Coal	0	4	6
Strata	10	0	7
Smith's Coal	0	2	2
Strata	12	1	1
Drowsall Coal (good quality)	0	3	0
Strata	9	0	8
Powell Coal	0	3	3
Strata	9	1	3
Two-yard Coal	0	6	0
Strata	11	0	0
Crank Coal	0	2	8
Strata with Brassey Ironstone	10	2	6
Brassey Coal	0	5	0
Strata with Black Band Ironstone 18 in.	10	0	11
Main Coal, with a parting of clay 18 in.	0	7	6
Total	156	0	10

Some valuable seams of ironstone occur in this coal-field, the principal being the "Brassey" and "Black Band;" this last measure abounds in fossil remains of fish scales, teeth, and also contains a bivalve shell of the genus Anthracosia.

The Flintshire Coal-field extends for a distance of fifteen miles along the western side of the estuary of the Dee to the point of Air, but throughout a considerable part of its range the productive portion is narrow and greatly broken by faults. The coal seams dip beneath the estuary, reappearing through a fault near Parkgate, and underlie the New Red Sandstone of the Cheshire plain. Professor Hull gives the following general section of this coal-field :—

SUCCESSION OF STRATA, FLINTSHIRE COAL FIELD.

	Ft.	In.
Four-foot Coal (Cannel Coal)	4	0
Strata	41	0
Bind Coal	2	6
Strata with ironstone	62	0
Hollin Coal (in three beds)	6	6

	Ft.	In.
Cannel	1	6
Strata with ironstone	29	0
Brassey Coal	3	0
Strata	82	0
Main Coal	7	0
Strata . . . . 180 ft. to	300	0
Lower Four-foot Coal (in some places Cannel	4	0

The main and Brassey Coal of Flintshire and Denbighshire correspond; the Hollin of the first is the Two Yard of the second, while the "Bind" and the "Powell" seams are identified, so also with the intermediate measures of ironstone of Flintshire; they also correspond with Denbighshire. These coal-fields were probably at one time continuous, though they are now divided by the Millstone Grit, and severed by the Great Bala fault, one of the most extensive in Great Britain, traceable from the sea on the coast at Merionethshire through Bala lake into Cheshire, and with a displacement of from 10,000 to 12,000 feet. The total area of the Flintshire coal-field is 35 square miles with an estimated thickness of 35 feet of coal.

The coal and shales of these coal-fields are of considerable importance as gas and oil producers, as well as being adapted to household purposes. Those employed for gas-making (cannel) in Flintshire constitute a large portion of the Hollin Coal, and of the Lower four-foot coal of Leeswood near Mold. This latter seam is reported to yield a larger percentage of gas than the far-famed Wigan cannel, but the rich gas-producing area is limited to a comparatively small district, and is being rapidly exhausted.

Analyses of the North Wales Coal.—The bituminous coals of Denbighshire, examined by Mr. Lewis Thompson, show the following constituents; the coals reported upon being seams worked in the Ruabon district, known as the following:—

Constituents.	Ruabon Coals.			
	Top Yard.	Main Seam.	Yard Seam.	Nant Seam.
Volatile matter	37·50	41·50	34·00	37·90
Coke	62·50	58·50	66·00	62·10
Ash	2·50	1·00	1·40	1·40
Sulphur in coal	1·40	0·85	1·10	1·10
,, in coke	0·80	0·45	0·60	0·70
,, in volatile matter . .	0·60	0·40	0·50	0·40
Ash in coke (per cent.) . .	4·00	1·70	2·10	2·20
Specific gravity	1·269	1·284	1·271	1·269

The Ruabon Main Coal in the above series yielding by far the greatest proportion of volatile matter is thus described: "Coal black and laminated; fracture irregular, inclining to cubical; cross-fracture, foliated and splintry, with numerous layers of charcoal and other indications of iron pyrites; streak, dull black. On the fire swells, and fuses together; ash, pale yellow."

The "Main Coal" and the "Two Yard Coal" worked by the Brymbo Company, Wrexham, employed as furnace and steam coal afford the following results on examination:—

RESULTS TABULATED.

Constituents.	Brymbo Main Coal.	Brymbo Two-yard.
Carbon	77·87	78·13
Hydrogen	5·09	5·53
Nitrogen	0·57	0·54
Sulphur	2·73	1·88
Oxygen	9·52	8·02
Ash	4·22	5·90
	100·00	100·00

The yield of coke from these coals is equivalent respectively to 55·40 and 56·20 per cent., the specific gravity being 1·301 and 1·283.

Other analyses made in Dr. Percy's laboratory in the Royal School of Mines by Mr. W. L. Ward, give the following results. The coal examined was obtained from the "Main Seam" and the "Crank Seam," Wrexham, Denbighshire.

RESULTS TABULATED.

Constituents.	Main Coal.	Crank Coal.
Carbon	78·44	81·29
Hydrogen	5·27	4·23
Oxygen and Nitrogen . .	8·30	6·77
Sulphur	0·99	0·91
Ash	2·15	2·50
Water	4·85	4·10
	100·00	99·80

The Main Coal yields when coked 61·38 per cent., the coke being somewhat lustrous and coherent, the colour of the ash light red. The Crank Coal, it should be observed, is a non-caking

coal; colour of the ash light red. This coal is largely composed of the fibrous charcoal-like stuff, commonly called "mother of coal."

The coal of several seams raised at the Ffrwd Collieries of Messrs. Sparow and Poole situated near Wrexham in Denbighshire, gave the following results on examination by Mr. Edward Riley. The annexed refers to the five feet coal, the best furnace coal of the district. The whole of the sample was intimately pulverised. It contained moisture 4·32 per cent. The coal dried at 212° Fahr., giving the following:—

RESULTS TABULATED.

Coke, per cent.	67·28
Sulphur	·94
Ash	4·27

The ash consisting of silica ·49 per cent, iron peroxide, and alumina, 3·06 per cent., with lime and traces of magnesia ·72 per cent.; a second analysis of the same coal giving 66·59 per cent. of coke, and 4·43 per cent. of ash.

The Powell coal examined consisted of three samples, each of which was pulverized separately, and an intimate mixture made of equal weights of the powder. The mixture gave moisture 3·48 per cent. The coal dried at 212° Fahr., giving the following:—

RESULTS TABULATED.

Coke, per cent.	66·61
Sulphur	4·15
Ash	6·61

The ash consisted of silica 1·14 per cent., oxide of iron and alumina 5·28 per cent., and an appreciable amount of phosphoric acid and lime, amounting to 0·19 per cent. A second sample of the same coal prepared under similar conditions gave of coke 67·18 per cent. and 6·50 per cent. of ash. This coal appears to be extensively used for lime-burning, brick-making, &c.; it is a caking coal and makes a good coke, it has been tried in the blast furnace, but it was found after some days' trial it would only make white iron.

Samples of the Top, Bind, and Bottom seams examined under similar conditions as the preceding seams, the samples being pulverized, and equal weights of each intimately mixed, gave of moisture 3·38 per cent., and dried at a temperature of 212° Fahr. the annexed results were obtained of two varieties:—

RESULTS TABULATED.

Constituents.	First.	Second.
Coke per cent.	67·91	67·01
Sulphur	1·15	...
Ash	2·25	2·48

The ash in the first analysis consisted of 0·68 per cent. of silica, oxide of iron and alumina 1·28 per cent., and 0·56 per cent. of lime with a little magnesia.

The second example examined is a furnace coal of second quality, containing but a small proportion of sulphur; so far as experience goes it does not appear to be a strong coal, crushing to some extent in the blast furnace, while as a coking coal it gives very good results.

Another seam of coal in the Wrexham district, examined also by Mr. Riley, name not stated, gave the annexed results. The coal contained moisture 4·79 per cent., giving when dried at 212° Fahr.:—

RESULTS TABULATED.

Coke, per cent.	66·31
Sulphur	0·96
Ash	1·48

The ash consisting of silica 0·45 per cent., oxide of iron and alumina 0·63 per cent., and 0·40 per cent. of lime, with a little magnesia. It is remarked of this coal that the ash is white in colour; the coal appears to make a hard coke, well adapted for use in the blast furnace, the percentage of sulphur being inconsiderable.

In this seam, and in others in the district, there are occasionally found thin veins or balls of iron pyrites; these when carefully removed not only increase the value of the coal, but render it available for use in the blast furnace.

The Flintshire Coals, described as free burning, strong, not binding, and leaving a white ash, the principal markets for which are Liverpool, Chester, Holyhead, the Isle of Man, and the local metallurgical establishments, give the following composition:—Those examined, the "Ewloe" and the "Bagillt Main Coal," are thus referred to. The Ewloe coal is a "splintry coal of a brown black colour, containing large quantities of mineralised charcoal and iron pyrites, although less white shale was observed than usually occurs in coals of this part of the principality." The

Ewloe coal is worked in the parish of Hawarden. The thickness of the seam varies from 8 to 10 feet, and occurs at a depth of 160 yards from the surface. The "Bagillt Main Seam" is a vein 5 feet thick, worked at a depth of 100 yards from the surface; the colliery is situated in the parish of Holywell, bordering on the River Dee, from which river it is distant about one mile. As steam coals they are found to light easily, burn freely, and blow off much steam. These coals evolve much smoke and soot, and a considerable amount of ash and cinder; the amount of clinker left, however, is small. The mean composition of average samples of these coals is as follows:—*

RESULTS TABULATED.

Constituents.	Ewloe Coal.	Bagillt Main.
Carbon	80·97	88·48
Hydrogen	4·96	5·62
Nitrogen	1·10	2·02
Sulphur	1·40	1·36
Oxygen	8·20	0·86
Ash	3·37	1·62
	100·00	199·96
Specific gravity	1·275	1·269
Coke per cent.	54·50	55·80
Weight of a cubic foot	54·51 lbs.	49·63 lbs.
Space occupied by a ton	44·44ft.	45·16 ft.

Cannel coal is not widely diffused in our coal-fields, the most noted localities being Wigan in Lancashire, the most important in Great Britain; and Leeswood (south of Mold), Flintshire; Gilmerton, near Edinburgh; Muirkirk, in Lanarkshire, and a few other localities in Ayrshire and Fifeshire. The character of cannel coal is very variable; where it occurs in its most perfect form, as at Leeswood Green, near Mold, Flintshire, the roof of the seam is usually of a rich oleaginous shale, from 4 to 10 inches through. Next below comes what is termed the smooth cannel, which is about 27 inches thick. This mineral is described as possessing a flat conchoidal fracture, and in addition to its more important commercial properties might, if required, be converted into jet-like ornaments. The smooth cannel passes insensibly down, trending into what is known and highly prized as "curly cannel," which may be said

* "Coals Suited to the Steam Navy," 3rd Report, pp. 16, 31, and 55.

to average 18 inches in thickness. The cannel seat or floor is a highly bituminous shale, occasionally passing into an impure coal, and associated with a black band ironstone. The aspect of the curly cannel is quite unique; it is lustrous, compact, and imperfectly conchoidal, with numerous flat circular disc-like appearances.

In a report on the Leeswood cannel, made by Dr. Andrew Fife, to ascertain its value as a gas-producing mineral, and also as a coke-giving coal, the annexed table noting the results of his examination exhibits the character, in comparison with other well-known cannels :—

	Leeswood smooth Cannel.	Leeswood curly Cannel.	Wigan Cannel.	Lesmahago Cannel.	Torbane or Boghead Coal.
Cubic feet of gas per ton	9,972	14,280	12,100	10,176	15,482
Durability of gas per foot: min. . .	58·05	82·30	48·35	70·00	84·40
Illuminating power per foot, candles .	8·2	1·09	5·00	8·70	10·30
Grains of sperm per foot	0·981	1·308	0·36	1·044	1·242
Value of coals in lbs. of sperm . . .	1401·7	2668·3	617·00	1517·0	2736·0
Comparative value of the coals . .	5·610	5·025	...	1·16	2·86

Production of Coal.—From Pennant, in his "Tour in Wales," * written in the year 1810, we have the following account of the Mostyn collieries in Flintshire :—" The collieries of Mostyn and Bychton have been worked for a very considerable time, and in the last century (the eighteenth) supplied Dublin and the eastern side of Ireland with coals. They were discovered in the township of Mostyn as early as the time of Edward I., as appears by an " Extent " of that place, in the 23rd year of his reign. They are at present in a low state, partly from the rise of the works at Whitehaven, but more from the loss of channel of the Dee, which in the beginning of this century flowed so close to our shore, that ships of 200 tons lay under this parish with their cables twisted round the trees. At present vessels of 60 or 70 tons cannot approach nearer than two miles, the Dee now flowing under the opposite shore. Still, we load a few vessels for Ireland, and some for North Wales. Much is also consumed by the neighbouring smelting-houses and the inland parts of Denbighshire.

* Thos. Pennant's " Tour in Wales," Vol. i., p. 23, 1810.

The improvement of land by lime has of late occasioned a great consumption of coal by the farmers, and by the persons who burn it for sale."

From the agricultural survey of North Wales, published in 1794,* it appears that there was but one colliery in Anglesea producing ten tons per day, or about 3,000 tons a year, and sold at 16*s.* per ton at the pit's mouth. The metallurgical works of the Pary's Mountain and Sulphur Company, now known as the Mona Smelting Works, appear to have been the only manufacture then carried on in the district. Until the year 1854 there does not exist any information showing the production of the coal-fields of North Wales, the output of the collieries being included with those of other coal-fields. In that year, however, 1,143,000 tons were raised from the 60 collieries then in operation in Denbighshire, Flintshire, and Anglesea, and in the following year 1,125,000 tons, the yield of 65 collieries.

In subsequent years the production of the respective coal-fields in North Wales are separately distinguished, the quantities being as follows, with the total number of collieries in the three coal-fields :—†

Year.	Number of Collieries.	Denbighshire.	Flintshire.	Anglesea.
	Nos.	Tons.	Tons.	Tons.
1856	81	527,000	519,500	‡
1857	84	527,000	519,500	‡
1858	81	525,000	497,000	‡
1859	81	1,039,500	587,500	35,000
1860	84	1,139,500	590,500	20,500
1861	78	1,250,000	600,500	19,750
1862	77	1,016,000	625,500	18,500
1863	81	1,078,500	631,500	18,000
1864	81	1,381,560	590,500	15,000
1865	84	1,395,000	575,000	12,500
1866	80	1,500,000	570,000	12,000
1867	75	1,475,250	885,500	10,500
1868	66	1,520,000	857,500	7,500
1869	65	1,427,701	725,288	2,191
1874	122	1,435,950	985,000	3,850
1875	124	1,379,560	955,500	2,248
1876	128	1,355,500	850,000	1,750
1877	112	1,622,500	855,750	1,330
1878	107	1,513,900	707,785	672
1879	105	1,498,985	720,697	...
1880	76	1,650,406	778,909	...

* The Rev. Walter Davies, M.A., 1794.

† Mineral Statistics. ‡ Included in Flintshire.

Summarising the above returns of the coal produce of North Wales, the following shows the number of collieries in each county, as also the total output:—

Year.	NUMBER OF COLLIERIES.			Total of North Wales.
	Denbighshire.	Flintshire.	Anglesea.	
	Nos.	Nos.	Nos.	Tons.
1854	25	30	5	1,143,000
1855	29	31	5	1,125,000
1856	34	42	5	1,046,500
1857	39	40	5	1,046,500
1858	39	37	5	1,022,500
1859	38	38	5	1,662,000
1860	39	40	5	1,750,500
1861	35	38	5	1,870,250
1862	31	41	5	1,660,000
1863	35	41	5	1,728,000
1864	35	41	5	1,987,060
1865	36	43	5	1,983,000
1866	35	40	5	2,082,000
1867	34	37	4	2,371,250
1868	29	34	3	2,385,000
1869	31	32	2	2,155,180
1870	23	28	2	2,329,030
1871	24	32	2	2,500,000
1872	38	34	2	*
1873	50	62	3	2,450,000
1874	59	60	3	2,425,300
1875	61	60	3	2,337,308
1876	61	64	3	2,207,250
1877	59	51	2	2,479,580
1878	54	51	2	2,222,357
1879	53	52	...	2,219,682
1880	38	38	...	2,429,315†

Cannel coal appears to have been discovered in Flintshire about the year 1862, at Leeswood, when 28,816 tons were raised. This quantity was increased to 120,000 tons in the year 1864, when the following collieries were raising cannel coal:—Leeswood Green, Leeswood Hill, Coed Talon, Coppa and Nerquis, all situated near Mold, and at Wern near Bagillt. The production of cannel in 1865 amounted to 150,000 tons in Flint-

* Included in West Lancashire, but estimated at 2,600,000 tons.
† Report H.M. Inspectors of Mines, 1880.

shire. The production of the seams yielding cannel the same year in the collieries of the United Kingdom was as follows :—

	TONS.
England	946,175
Wales	150,000
Scotland	322,000
Total	1,418,175

The yield of cannel coal not being separately distinguished from that of bituminous coal and anthracite since the above-named year, the following details of the quantity raised in England in 1865 will generally indicate those coal-fields from which the cannel coal was then obtained :—

COUNTIES.	TONS.
South Staffordshire	10,000
Nottinghamshire	46,950
Derbyshire	42,225
Yorkshire	185,000
Lancashire	650,000
Cheshire	12,000
Total production in England	946,175

Of the total cannel coal raised in the year 1865, it was estimated that 250,000 tons were submitted to distillation for coal-oil, leaving 1,168,175 tons available for gas manufacture and other purposes.

Distribution of Coal.—The coal of North Wales has long enjoyed a high reputation for various commercial purposes, and is extensively employed as a steam coal, for gas manufacture and coking, and some varieties for the blast-furnace and foundry. As a house coal some seams of the Ruabon district, in Denbighshire, are especially suitable, and these coals are in good demand in the midland counties and the metropolis. The early returns bearing on the distribution of coal from North Wales are not important; those returns, however, of recent years, show in a marked manner the increasing demand. The following table giving the quantities carried out of the district by the London and North-Western and Great Western Railways, will show the extent of the distribution since 1863 :—

Year.	London and North-Western Railway.	Great Western Railway.
	Tons.	Tons.
1863	196,957	...
1864	216,043	...
1865	305,000	625,291
1866	310,863	600,000
1867	372,755	627,355
1868	381,668	703,379
1869	321,367	611,524
1870	376,512	646,810
1871	391,516	839,090
1872	408,667	967,855
1873	481.284	950,746
1874	464,808	864,162
1875	424,118	802,763
1876	368,554	1,055,775
1877	373,464	1,183,205
1878	328,325	988,675
1879	316,200	952,154
1880	304,509	960,934

While the above figures exhibit the increased distribution of the North Wales coal since the year 1863, the London and North-Western Railway, it appears, carried over its extensive system from the several coal-fields which it traverses in the same year, 3,756,111 tons, increased to 8,299,491 tons in the year 1873, and 11,100,891 tons in the year 1880. The Great Western Railway in the same manner carried a total of 382,104 tons in the year 1857, increased to 6,412,798 tons in the year 1877, and 6,909,968 tons in the year 1880.

Population employed in Coal Mining in North Wales. ANGLESEA.—The number employed in the year 1854 in coal mining was 51 persons of all ages. Not again until 1874 do any returns appear; in that year, however, and until 1878, the numbers employed under and above ground are as follows:—

Year.	PERSONS EMPLOYED.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	32	20	52	3,746	72
1875	15	7	22	2,248	102
1876	12	7	19	1,820	96
1877	10	7	17	1,320	77
1878	7	6	13	672	51

DENBIGHSHIRE.—The number engaged in coal mining in the year 1854 was 3,017, and in iron mining three persons. The quantity of coal raised being included in the production of North Wales, which in that year amounted to 1,143,000 tons, the total number of persons engaged in its output being 4,623, of whom 1,555 were in Flintshire, and 51 in Anglesea. Since the year 1874 the figures are as under :—*

Year.	PERSONS EMPLOYED.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	6,488	1,628	8,116	1,431,959	176
1875	6,419	1,683	8,102	1,381,380	171
1876	5,947	1,497	7,444	1,560,388	210
1877	5,228	1,444	6,672	1,618.077	243
1878	5,025	1,232	6.257	1,514,829	242
1879	5,377	1,278	6,655	1,499,857	225
1880	5,689	1,270	6,959	1,650,406	237

In the year 1879 the ages of those employed above and below ground are thus distinguished :—

All Ages.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
Between 12 and 13 .	33	...	33
,, 13 and 16 . .	398	98†	496
,, 10 and 13 .	...	7‡	7
Above 16	4,946	1,173§	6,119
Total . .	5,377	1,278	6,655

FLINTSHIRE.—The total number of persons of all ages engaged in coal mining in Flintshire in the year 1854 was 1,555. Occasional returns are met with in later years, but none sufficiently complete for comparison. In 1874,|| and since the necessary data are available, and appear in the annexed table, showing the numbers employed, the quantities of coal raised, and the average produce per man :—

* Reports of H.M. Inspectors of Mines.
† Including 11 females. ‡ Including 4 females. § Including 61 females.
|| Report H.M. Inspector of Coal Mines, Mr. Henry Hall.

Year.	PERSONS EMPLOYED.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	4,567	1,401	5,968	993,332	166
1875	4,266	1,208	5,474	965,490	176
1876	3,472	1,046	4,518	855,257	189
1877	3,078	1,029	4,107	854,923	208
1878	2,608	766	3,374	708,724	210
1879	2,733	754	3,487	721,697	207
1880	2,633	616	3,249	778,909	240

In the year 1879 the respective ages of those employed are classified as follows :—*

All Ages.	Under Ground.	Above Ground.	Total.
	Nos.	Nos.	Nos.
From 13 to 16 . .	108	86	194
Above 16	2,625	668	3,293
Total . .	2,733	754	3,487

Summarising the number of persons employed in the coal-fields of Anglesea, Denbighshire, and Flintshire, for the seven years ending 1880, the annexed table shows the aggregate employed in North Wales, with the total output of coal, which is supplemented by the average output of coal per man for the whole district :—*

Year.	PERSONS EMPLOYED.		Total.	Coal Raised. North Wales.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	11,087	3,049	14,136	2,429,037	172
1875	10,700	2,898	13,598	2,349,118	172
1876	9,431	2,550	11,981	2,417,965	202
1877	8,316	2,480	10,796	2,474,320	229
1878	7,640	2,004	9,644	2,224,225	230
1879	8,110	2,032	10,142	2,221,554	220
1880	8,322	1,886	10,208	2,429,315	238

Mr. H. Hall, in 1879, gives the average quantity of coal raised per man in North Wales as 220 tons, and in West Lancashire also, in his inspection district, 326 tons. This apparent deficiency

* Reports H.M. Inspector of Coal Mines, Mr. Henry Hall, West Lancashire and North Wales.

in individual efficiency, Mr. Hall remarks, appears from year to year, and it is difficult to fix the cause. "The 'output' at many of the North Wales collieries is very small, and machinery for hauling is not so general as in other districts, thus entailing more manual labour, and the demand for the class of coal produced is not such as to keep the collieries constantly at work; nor is the atmosphere of many of the mines such as is likely to encourage energetic labour."

Resources of the North Wales Coal-fields.—The total number of statute foot acres of coal wrought and unwrought in the North Wales coal-fields as enumerated by Mr. Joseph Dickinson, in the "Coal Commission Report," * amounts to 2,585,315 acres, and of this area 364,210 acres have already been wrought at the date of the Report (1870).

The acreage of the respective coal-fields, the depths of coal from surface, the total originally existing, and those portions wrought, appear in the annexed statement:—

North Wales Coal-fields.	DEPTHS FROM THE SURFACE.			Portion already Wrought.
	Not exceeding 3,000 feet.	Between 3,000 and 4,000 feet.	Total Wrought and Unwrought.	
	Acres.	Acres.	Acres.	Acres.
Anglesea . .	7,513	...	7,513	1,959
Denbighshire . .	915,882	299,080	1,214,962	80,000
Flintshire† . .	1,362,840	...	1,362,840	282,251
Total acres .	2,286,235	299,080	2,585,315	364,210

Of the acreage of coal yet remaining in the above coal-fields, considerable reductions for faults, supports, barriers, &c., are made, leaving the portion unwrought, likely to be clear for working, 1,435,788 statute foot acres. This acreage is apportioned as under:—

North Wales Coal-fields.	Acreage remaining unwrought.	Acreage unwrought deducted for faults, barriers, &c.	Acreage unwrought likely to be clear for Working.
	Acres.	Acres.	Acres.
Anglesea	5,554	1,586	3,968
Denbighshire . . .	1,134,962	215,622	919,340
Flintshire	1,080,589	568.109	512,480
Total . . .	2,221,105	785,317	1,435,788

* Vol. i., p. 18. † Including Neston in Cheshire and the Estuary of the Dee.

In the computation of the acreage remaining unwrought, and likely to be clear for working, an allowance of one-fourteenth has been made for unavoidable loss and waste in working, and 1,400 tons have been taken as the average yield of each foot acre. This estimate gives to each of the North Wales coal-fields the available quantities as follows, in statute tons of 2,240 lbs.:—

North Wales Coal-fields.	Tons of Coal remaining unwrought in each Coal-field.
	Tons.
Anglesea	5,000,000
Denbighshire	1,287,000,000
Flintshire	718,000,000
Total	2,010,000,000

With the production of 1870,* amounting to 2,329,030 tons, and the above quantities, supplies would be available for 863 years. Deducting the production of North Wales for the ten years ending 1879, amounting to 23,770,507 tons, there remains 1,986,229,493 tons. This at the average of the ten years (2,377,050 tons), would afford supplies for 839 years; while, if the year of greatest production be taken (1872), when 2,600,000 tons were the output, the exhaustion of these coal-fields at that rate would occur 764 years hence.

* Mineral Statistics of the United Kingdom.

CHAPTER XIV.

SOUTH WALES COAL-FIELD.

Description of Coal-field, including its extension through the Counties of Pembroke, Glamorgan, Caermarthen, Breckon, and Monmouthshire—The Thickness of Strata and Seams of workable Coals—Analyses of the several varieties of Coal, Anthracitic and Bituminous—Coke manufacture at Ebbw Vale—The Coppée Process—The Bességes Process as carried out in France—Production of Coal-field—Parish Returns—Deep Winning at the Harris Navigation Pit—Bute Docks—Distribution of Coal Coastwise to Foreign Countries and by Railway—Prices and Cost of Production—Resources and probable Duration of Coal-field.

The South Wales Coal-field.—Excepting the coal basin of the Clyde in Scotland this is the largest coal-field in Great Britain, having a total area of 1,000 square miles, and a vertical section of strata associated with the coal measures of between 11,000 and 12,000 feet. The coal-field occupies a large area of the county of Glamorgan, and its extension appears in the neighbouring counties of Monmouth, Brecon, Caermarthen, and Pembroke, distributed as follows:—

COUNTIES.	SQUARE MILES.
Monmouthshire	104
Glamorganshire	518
Brecknockshire	74
Caermarthenshire	228
Pembrokeshire	76
Total	1000

Risca, Pontypool, and Blaenavon mark the eastern limit of the coal-field in Monmouthshire, from Pontypool to Saint Bride's Bay in Pembrokeshire, the western limit of the coal-field; its greatest length is about 89 miles; its greatest breadth in Glamorganshire being about 21 miles. From Abersychan, in Monmouthshire, to the Glyncorrwg Fault in Glamorgan, the length is 24 miles and the average width 13 miles. From the Glyncorrwg Fault going west to Neath, a distance of 9 miles, the average width is 20 miles. At Aberafon, 5 miles due south of Neath, a portion of the coal-field runs beneath Swansea Bay for a distance of 9 miles, and with an average breadth of

2½ miles, appearing again at Oystermouth. From the latter place to Kidwelly, a distance of 14 miles, it has an average breadth of 14 miles; a considerable portion of this part of the coal-field, however (9 miles long by 5 miles broad), lies beneath the estuary of the Burry and Llwchwr rivers. At Kidwelly the whole coal-field is lost beneath the waters of Caermarthen Bay, reappearing at Amroth, in Pembrokeshire; the portion beneath the sea being 15 miles in length, with an average width of 6 miles. From Amroth the coal-field runs uninterruptedly to Saint Bride's Bay, a distance of 20 miles, with an average breadth of only 5 miles. North of Walton, West Pembrokeshire, at the westernmost extremity of the field, the coal-measures take a sudden bend to the north for a distance of 5½ miles, with an average width of 1½ miles. This latter portion, however, is not taken into consideration in estimating the length of the coal-field. The average width west of the Glyncorrwg Fault is 9½ miles. From the exhaustive paper of Thomas Foster Brown, Esq., F.G.S., former President of the South Wales Institute of Engineers, on the South Wales coal-field, the foregoing facts are gathered, as also are the following general references to the geological succession of rocks in the area of the coal-field.

The Coal Measures repose principally on the millstone grit; westward, however, of Swansea Bay the millstone grit disappears, and the Lower coal-measures repose upon the Mountain limestone, and still further west the coal-measures lie immediately upon the Lower Silurian rocks. The millstone grit is of the usual lithological character of these beds; it contains few fossils. At its base occurs a stratum of conglomerate about 20 feet in thickness, its maximum thickness, where fully developed, being 220 feet. This formation is often confounded with the Farewell rock of the district, which is a true marine stratum lying above the millstone grit and in the true coal-measures.

The Mountain Limestone, immediately underlying the millstone grit and resting upon the Old Red Sandstone, is generally seen to dip, where it is exposed, conformably with the coal-measures. On the north of the coal-field the limestone ridge reaches a considerable altitude, in some places being more than 1,200 feet above the sea, while on the south crop the usual height is from 400 to 500 feet. The limestone is divisible into two horizons; first, upper beds, consisting of alternating dark shales, with bands of limestones passing downwards into massive beds

of the latter, the aggregate thickness being about from 700 to 1,000 feet.

The Old Red Sandstone, Upper Devonian, occupies a large proportion of the district under consideration. It consists of conglomerates, red and brown sandstones, marls, and calcareous cornstones, from 8,000 to 10,000 feet in thickness. On the north of the field these beds form the highest ground in South Wales, rising to the height of 2,910 feet above the level of the sea.

Silurian.—This formation consists of the Upper Silurian rocks (Ludlow and Wenlock series) in the east, and Middle Silurian (Llandovery rocks), and Lower Silurian (Llandeilo flags) in the west. Their thickness probably averages between 600 and 700 feet. They form tolerably high ground on the east of the coal-field, between Pontypool and Usk in Monmouthshire. South of Llandegfydd in the same shire, they are lost beneath the Old Red Sandstone, cropping up again around Llanfrechfa, three miles north of Newport, and again at Malpas, Penrhas, Llanhennock and Christchurch, all within a few miles from Newport. On the west, after striking beneath the beds of the Old Red Sandstone for some distance, they re-appear on the surface near Saint Mellon's; from whence they run uninterruptedly to Pen-y-lan and Rumney, near Cardiff. In the west of the coal-field the Lower Silurian beds occupy a great portion of the counties of Caermarthen and Pembroke, by far the larger part of which is occupied by the Llandeilo flags, while the upper Llandovery rocks only occur on the southern border, between Langwm, Pembrokeshire, and Saint Bride's Bay.

The Coal Measure Series.—According to Mr. Vivian's Coal Commission Report in the South Wales' coal-field, the whole series of strata, from the uppermost Pellengare beds down to the millstone grit, is from 10,000 to 12,000 feet in thickness, containing about 80 seams of coal, of which 25 are from 2 feet upwards, with an aggregate thickness of 84 feet of workable coal. In the eastern part of the coal-field in Monmouthshire, according to Mr. Clarke of Dowlais, Coal Commission Report, the coal-measure series has a thickness of 11,650 feet, consisting of "Shales, with ironstones; sandstones, including the Gower series, and coal-beds of which there are about 25 more than 2 feet thick." The coal-measures are thus divided:—

Upper Pellengare Series, more than 3,400 feet.
Pennant Grit Series (Swansea), 3,246 feet.
Lower Coal Measures, 450 to 850 feet.

The upper series are thus divided: the first, consisting of shales and sandstones, down to the Mynyddysllwyn coal; the second strata, with 26 coal-seams, down to the Hughes Vein, 9 of the seams being over 2 feet thick; the Pennant Grit series, consisting of hard and thick bedded sandstones, &c., with 15 coal-seams, 5 of which are over 2 feet thick; the Lower coal-measures, consisting principally of shales, rich in ironstone and coal-seams, of which there are 34 in all, 8 of which exceed 2 feet in thickness.

The character of the coals of this great coal-field vary considerably in their chemical composition, as will be shown. The seams occupying the north-east side of the basin are chiefly coking or partly bituminous, those to the north-west are anthracitic. Again, on the south side of the basin, the seams are bituminous or gaseous, while the seams in the centre of the coal-field are known as semi-bituminous or steam coals. In the Aberdare area, in Glamorganshire, the seams are of that kind known as free burning and smokeless, hence their great importance for steam purposes, especially the Aberdare "Four Feet" steam coal, which is now nearly exhausted.

Analyses of the Coal.—Household, general manufacturing, and colliery coals are raised in the eastern part of the coal-field from the Upper and Lower Pennant Grit series. In the neighbourhood of Maesteg the lower coal-measures appear at a comparatively shallow depth, also at Carnarvon to the west; further to the west the same conditions appear, also to the northern, southern, and western edges of the basin, while in the inner area of the coal-field the Upper Pennant series is developed.

From the Merthyr, Taff Vale, and Rhondda Valleys the steam coal is principally obtained from the seams in the Lower coal-measures; on the northern outcrop, from Hirwain to Blaenavon, the coal raised is principally employed in the manufacture of iron at the several works in the limits above named.

The western limits of the coal-field alone produce anthracite. "As a mineral, anthracite occurs massive and amorphous; has a subconchoidal fracture, less or more of a metallic lustre, of a greyish-black or iron colour; streak unaltered, conducts electricity perfectly, and burns with a very weak or no flame." *

* Dr. Page's "Economic Geology."

The following analyses exhibit generally the chemical constituents of some of the principal anthracite coals of South Wales :—

Districts.	Carbon.	Volatile Matter.	Ashes.
Neath Abbey . .	91·08	5·01	4·00
Swansea	89·00	7·50	3·50
Ystalyfera . . .	92·46	6·04	1·50
Cwm Neath . . .	93·12	5·22	1·50

This variety of coal is also largely employed in the hop-drying and malt manufactures, while the small is much in request for the burning of lime. The annexed analysis exhibits the ordinary composition of the "Brass Vein" of the Cwmllynfell Colliery in Glamorganshire, also yielding anthracite. The seam is 4 feet thick, and takes its name from a vein of pyrites which runs through it; the coal in its immediate vicinity is considered by the colliers to be brighter, harder, and purer than any other portion of the seam. The analyses, side by side, is of anthracite from the Bonville Court Colliery, in Pembrokeshire, and Gwendraeth, in Caermarthenshire :—

Constituents.	Brass Vein.	Bonville Court.	Gwendraeth.
Carbon	91·44	94·18	92·17
Hydrogen	3·46	2·99	3·10
Nitrogen	·21	·76	1·08
Sulphur	·79	·59	·34
Oxygen	2·58	·50	2·22
Ash	1·52	·98	1·09
	100·00	100·00	100·00

The respective yield of coke being 92 and 93 per cent.

The coal-seams, as developed in the Western district of the coal-field in Pembrokeshire, are exclusively of the anthracitic variety. The same may be said generally of the north crop of the coal-field east of Caermarthen, while the south crop yields coal of a bituminous character, the centre of the basin yielding a free burning coal.

Beyond the above the annexed analyses gives the constituents of the following well-known seams of anthracite in South Wales :—

Constituents.	CAERMARTHEN.		PEMBROKE.	
	Pontyeats.	Big Vein.	Timber Vein.	Watneys.*
Carbon	91·16	88·7	93·0	92·17
Oxygen	2·74	7·4	1·67	2·22
Nitrogen	·91		·54	1·08
Hydrogen	3·11		3·08	3·10
Sulphur	·86	·5	·68	·34
Ash	1·12	3·4	1·03	1·09
	99·90	100·0	100·00	100·00

The valuable qualities of anthracite as a fuel have been long known and appreciated. Dr. Frankland who, in 1850, made careful analyses of the coal obtained in the neighbourhood of Saundersfoot; † recognises four special points connected with anthracite which especially recommend it as a steam coal. These are:—"the high evaporative power; the very small quantity of sulphur which it contains, and its entire freedom from iron pyrites (metallic cinder); the small amount of ash and clinker; and its requiring no stoking, and the entire absence of smoke during its combustion; these qualities, it may be further observed, are such important considerations, that although there are several bituminous coals which have, according to the Admiralty experiments, nearly the same evaporative power when well stoked, yet, in practice, would be found very greatly inferior because it is impossible to get the stoker to take the requisite trouble. This coal, however, places the manufacturer independent as it were of his stokers, who even by the most careless firing could scarcely perceptibly reduce its evaporative power."

The constant increase of evaporative power, with the increase of draught, as exhibited in the following experiments, indicates that a still higher result would be obtained with a stronger draught such as an ordinary steam shaft commands; but this is by no means the case with bituminous coals, which frequently give much better results with a slow than with a quick draught.

The following gives a comparative summary of the chief characteristics fitting coal for the mercantile marine. The first in the list is an anthracite coal, those following are some of

* Analysis, by Dr. Lyon Playfair.

† Report, printed by R. Mason, Tenby, 1850.

the most important varieties in the kingdom, and are intended for comparison :—

Name of Coal.	Pounds of Water evaporated by one pound of Coal.	Cubic feet occupied by one ton.	Cohesive Power of Coal (per centage of large coal).	Pounds of Clinkers per ton of Coal.
Bonville's	9·39	41·29	77·0	7·2
Pentrefelin . . .	7·40	33·85	52·7	23·0
Dalkeith	7·10	44·98	85·7	62·2
Wallsend, Elgin . .	8·67	41·02	64·0	14·6
Neath Abbey . .	9·65	37·77	50·0	19·2
Newcastle, Hartley . .	8·65	44·35	78·5	17·0
Original Hartley . .	6·98	45·62	80·0	10·1
Haswell's Wallsend . .	7·85	45·25	79·5	9·8
Cowpen Hartley . .	7·02	46·76	74·0	3·7
Pontypool . . .	8·04	40·216	57·5	20·9

In addition to these advantages are the economic weight (space occupied by one ton), and great cohesive power possessed, which renders it a very valuable fuel for sea-going vessels, whilst its composition and general freedom from iron pyrites furnish a fair guarantee of its being little liable to spontaneous combustion.

Comparing the anthracite with other coals examined and reported upon in the Admiralty investigation, the annexed table of the constituents of the coals previously referred to, shows, in a remarkable manner, the purity of the anthracite :—

Name of Coal.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Ash.
Bonville's Coal . .	94·16	2·99	·50	·59	·90
Pentrefelin	85·52	3·72	trace	·12	6·00
Pontypool . . .	80·70	5·66	1·35	2·39	5·52
Dalkeith (Jewel Seam) .	74·55	5·14	·10	·33	4·37
Wallsend Elgin . . .	76·09	5·22	1·41	1·53	10·70
Neath Abbey . . .	89·04	5·05	1·07	1·60	3·55
Newcastle Hartley . .	81·82	5·50	1·28	1·69	7·15
Original Hartley . .	81.18	5·56	·72	1·44	3·08
Haswell Steam Wallsend	83·76	5·31	1·06	1·21	5·94
Cowpen Hartley . .	82·20	5·10	1·69	·71	2·33

In the first report by De la Beche and Playfair on the coals suited to the steam navy * it has been shown that the true practical value of coals for steam purposes depends upon a combination of qualities which could only be elicited by carefully and properly

* See "Memoirs of the Geological Survey," vol. ii., part 2, p. 558.

continued experiments. These qualities, so far as regards steam ships of war, are referred to as follows:—

1. The fuel should burn so that steam may be raised in a short period, if this be desired; in other words, it should be able to produce a quick action.
2. It should possess high evaporative power, that is, be capable of converting much water into steam with a small consumption of coal.
3. It should not be bituminous, lest so much smoke be generated as to betray the position of ships of war when it is desirable that this should be concealed.
4. It should possess considerable cohesion of its particles, so that it may not be broken into too small fragments by the constant attrition which it may experience in the vessel.
5. It should combine a considerable density, with such mechanical structure that it may easily be stowed away in small space; a condition, which in coals of equal evaporative values, often involves a difference of more than 20 per cent.
6. It should be free from any considerable quantity of sulphur and should not progressively decay, both of which circumstances render it liable to spontaneous combustion.

Bituminous coals exhibit several varieties adapted to special purposes, known commercially as steam coal, furnace coal, household coal, gas coal, and coking coal. Those suited for raising steam are usually hard, burn open, and give a white heat; for the smelting of the ores of iron those free from sulphur and other impurities are selected. A good household coal is that which burns with a cheerful flame and leaves comparatively little ash. Gas coals are those which yield a large amount of dry, incondensable gas, and coking coal, such as yield a hard, dense, crystallized coke, capable of resisting the blast in the furnace.

The annexed are analyses of some of the principal coals wrought in the eastern part of the coal-field in Monmouthshire, from the Abercarne, Cwm Tylery, and Risca collieries, situated near Newport, and the Cwm Ffrwd colliery near Pontypool. These coals are in good demand for steam, furnace, and domestic purposes:—

MONMOUTHSHIRE COALS.

Constituents.	Charcoal Vein.	Rock Vein.	Black Vein.	¾ Rock Vein.	New Black Vein.
Carbon	81·26	82·25	81·78	75·15	83·68
Hydrogen	6·31	5·84	4·73	4·93	5·21
Nitrogen	·77	1·11		1·07	
Sulphur	1·86	1·22	6·69	2·85	8·87
Oxgen	9·76	3·58		5·04	
Ash	2·04	6·00	6·80	10·96	2·24
	102·00	100·00	100·00	100·00	100·00

Other analyses of the Black Vein steam coal, raised at Celynear Colliery, near Merthyr, and of Merthyr steam coal, show the following results :—

Constituents.	Black Vein.	MERTHYR.	
		Coal.	Coked and Dried.
Carbon	85·98	90·00	Coke. 87·92
Hydrogen	4·70	4·37	4·37
Sulphur	·59	0·90	0·90
Nitrogen	·90	0·51	0·51
Oxygen	5·53	3·14	4·88
Ash	2·30	1·08	1·08
	100·00	100·00	99·66

The Black Vein coal examined by Mr. Thomas Crowder, F.C.S., of Bristol, is described as igniting readily and giving an intense heat, with a bright flame, and making a clean fire; it is small, without washing, yielding a coke of very good quality. The practical heating power of the coal is excellent; one pound of the coal will convert nearly 14 lbs. of boiling water into steam. The analysis of the Merthyr coal and coke was made by Mr. William A. Miller.

The yield of coke from the above and other seams of the district being :—

	PER CENT.
Charcoal Vein	68·40
Rock Vein	68·80
Black Vein	71·80
Three-quarter Rock Vein	62·50
New Black Vein	68·00
Bedwas	71·70
Elle Vein	70·00
Nantygroes	65·60
New Rock Vein	70·00

Of the Caermarthenshire coals a few examples will indicate generally the composition of the seams named, the coals raised from these seams being employed extensively for steam, furnace, and domestic purposes :—

CAERMARTHENSHIRE COAL.

Constituents.	Pump Quart Seam.	Fiery Vein.	Fiery Vein.	Llangennech.
Carbon	92·17	87·87	88·66	85·46
Hydrogen	3·10	3·93	4·63	4·20
Nitrogen . . .	1·08	2·02	1.43	1·07
Sulphur	·34	·83	·33	·29
Oxygen	2·22	7·04	1·03	2·44
Ash	1·09		3·92	6·54
	100·00	101·69	100·00	100·00

These and other coals of the district yield coke in the following proportion :—

Fiery Vein . . . . 79·80 per cent.
Llangennech . . . . 83·69 ,,
Bynea, Fiery Vein . . . . 88·10 ,,

Of the bituminous coal of South Wales the Mynyddysllwyn Seam, in the Newport district, in Monmouthshire, has obtained the greatest celebrity. This seam may now be said to be all but exhausted. Of the free burning or steam coal, in the Glamorganshire area, the seam worked by the Messrs. Cory, Yeo and Company, known as the Graig Merthyr, or "Six Feet Vein," or "Graigola Vein" is the chief, it is worked extensively, and in the coal markets far and wide enjoys a deservedly high reputation, being generally regarded as the best steam coal of the district. The seam is identified with the Cwmclydach Colliery, and locally known as the "Graigola Seam," and is identical with the Six Feet Seam on the north crop of the coal basin. The composition of this and other veins in Glamorganshire appears as follows :—

Constituents.	Six-feet Seam.	Nine-feet Seam.	Nixon's Merthyr.	Birchgrove Graigola.	Thomas' Merthyr.
Carbon	88·28	86·18	90·27	84·25	90·12
Hydrogen	4·24	4·31	4·12	4·15	4·33
Nitrogen . . .	1·66	1·09	·63	·73	1·00
Sulphur	·91	·87	1·20	·86	·85
Oxygen : . . .	1·65	2·21	2·53	5·58	2·02
Ash	3·26	5·34	1·25	4·43	1·68
	100·00	100·00	100·00	100·00	100·00

The specific gravity and yield of coke of the foregoing and other varieties of coal of this district are shown in the annexed table:—

Coal Seams.	Specific Gravity.	Yield of Coke.
Six-feet Seam	1·31	85·83
Nine-feet Seam	1·33	86·54
Nixon's Merthyr	1·31	79·11
Birchgrove Graigola . . .	1·36	85·10
Thomas's Merthyr	1·30	86·53
Powell's Duffryn	1·326	84·30
Aberaman Merthyr . . .	1·305	85·00
North Duffryn	1·35	82·25
Gadly's Nine-feet	1·33	86·54
Gadly's Four-feet	1·32	82·23
Cwmbach Four-feet . . .	1·31	85·83
Cwmbach Six-feet	1·31	85·83

In reference to the economy of coal in working it may be interesting to refer generally to the point. Writers of experience say that in the Gwendraeth Valley coals "break out" four-fifths large, the remainder small, while the bituminous coal of the neighbourhood of Swansea does not cut out more than one-fourth large, and some not even this. The free burning coal found in the centre of the coal-field from Tyr Cenol, Morriston, and Swansea Valley on the east, through Coalbrook Colliery to Llanelly on the west, is of this character.

In South Wales, as in Durham, coke manufacture is carried out on an extensive scale. In the Durham district the ovens generally employed are of the type known as the "bee-hive," already described, but some modified forms are now being introduced. In South Wales the form of oven is almost rectangular, their construction giving the following average dimensions:—Width at the front, 6 feet, and at back, 5 feet; length of oven, 14 feet, and the height, inside to crown of arch, 5 feet. These ovens are generally built back to back, with chimney between them, and several have side and bottom flues.

This form of oven is charged sometimes at the door and sometimes at the top. The usual charge is 4½ tons for the first three days in the week, and for the remaining four days, 5 tons. For the coking of the smaller charge 72 hours are generally allowed, and 96 hours for the larger charge. The charge, which consolidates upon a wrought-iron bar laid along the length, and another transversely to it at the back of the oven, is drawn by means of

a windlass. The cooling of the coke is sometimes done in the oven and sometimes after the coke is drawn. At some works the small coal is washed before being coked, and the result is a denser and more valuable description of coke.

With respect to the ordinary "Bee-hive ovens," experience has shown that the coke burnt in them for fewer hours was inferior for smelting purposes to that burnt for a longer period, owing to its not being so easily oxidised; the more intense combustion of the purer carbon and its greater density fitting it more thoroughly for its work. The usual time occupied in burning is from 72 to 96 hours.

By the Belgium process of Coppée the coke is made in about 24 hours; this system is in operation at the works of the Ebbw Vale Company, where they were erected in the year 1874. The Coppée ovens are usually constructed in batches of 30 each, and were designed for coking only finely divided coal, such as is produced by crushing coal in a disintegrator. The chief advantages claimed by the system are rapidity of coking, largely increased yield (which is considered to be the most important advantage), and better coke. The chief characteristics of the "Coppée oven" are,—a small width and an arrangement of channels especially suited for poor coals; a combustion of gas by a double admission of air, which entirely suppresses the smoke; the combination of all the hot gases in a large conduit beneath the ovens and their utilization for heating boilers; and galleries for cooling and preserving the brickwork.* The mode of working at Ebbw Vale is thus described. The small coal is first washed to free it from intermixed shale, and then crushed in a Carr's disintegrator. It is next lifted by suitable machinery into a large cast-iron bin (capable of holding about 200 tons of crushed coal,) the bottom of which is sufficiently high above the tops of the ovens to allow the trams to run under it. When filled, the trams are pushed by hand along to the top of the oven for which the charge is intended; the previous charge not having yet been withdrawn. The front and back doors of the oven are now opened and the mass of coke, 30 feet long, 8 feet high, and 16 inches thick, is pushed out of the oven. This is effected by a ram, the face of which presses against the coke. This face

* For details of the Coppée Oven, see Dr. Percy's "Metallurgy," Fuel, p. 545.

is a little smaller than the cross-sectional area of the oven, and is fixed to the end of an iron girder, somewhat longer than the oven, and having a rack on its upper surface worked by a pinion. The whole is set upon an iron frame, together with a small engine and boiler, and the frame is mounted on wheels, rails being laid down in front of the ovens from end to end of the batch. The machine can be brought opposite each oven in turn. The ram having pushed the coke out of the oven is then drawn back as quickly as possible and the lower doors are closed. The oven is then immediately charged through three openings in the top by drawing out the slides in the bottom of the trams, and the coal is levelled by two men by means of rakes, which are introduced through the upper doors at each end of the oven and reach to its centre. The upper doors are then closed, and together with the lower doors, carefully luted to prevent access of air to the coal; carbonization immediately commences owing to the heat of the oven and to the circulation of the heated products from the adjacent ovens through the contiguous flues.

The process of emptying and refilling the oven as above described need not occupy more than eight minutes. The coke is quenched immediately after leaving the oven; to facilitate this operation the mass of coke which is pushed out of the oven is divided vertically and longitudinally into two equal parts by means of a drag. This separation is easily effected, since carbonization takes place from the two sides towards the centre, whereby a vertical plane, similar to a plane of cleavage, is formed through the centre of the mass of coke.* The ovens are numbered consecutively; the odd numbers are emptied and recharged in the morning and the even numbers in the afternoon, six days a week. Six charges are thus coked in each oven per week, each charge yielding about two tons of coke. The steam required for the coal-washing machine and for the disintegrator is generated by the waste heat of the ovens. An examination of the coke prepared by the Coppée system gives as much as 6 per cent. of water, a point of considerable importance in estimating the yield, which on a large scale, with coal containing 20 per cent. of shale, gives 62·5 per cent. of coke. It is remarked, that although the

* An explanation of this curious result is given in Dr. Percy's "Metallurgy," Fuel, in the remarks upon experiments on the formation of coke in the Appolt oven, p. 451.

coke made in the Coppée's ovens is doubtless sufficiently firm to withstand the weight of the overlying mass in the blast furnace, yet the large quantity of water contained in it, unless it be quenched with more than ordinary care, is a serious drawback to its use in such furnaces.

Mr. Emerson Bainbridge, who has gone very fully into the respective merits of the "Beehive" and "Coppée" systems of coke manufacture, has prepared the following summary of the chief points of comparison, which exhibit some interesting features :—*

	Beehive.	Coppée.
First cost per 2 tons of coke per day	£119 7s.	£100
Time of burning	48 to 120 hours	24 hours
Area per ton of coke daily . .	1,218 sq. ft.	234 sq. ft.
Per cent. of yield	45 per cent.	59 per cent.
Outside cooling surface per 2 tons .	1,002 sq. ft.	175 sq. ft.
Time in emptying and refilling .	60 minutes	8 minutes
Units of heat in waste gases per oven	966,710	1,401,584
Labour charge per ton . . .	1s. 3d.	11d.

The coke manufactured in the ordinary way in South Wales, although exceedingly hard and dense, does not appear to have attained all the economical results possible; experience has shown that the carbonization of the coal is not complete, the long, deep fissures in the coke thus manufactured exhibiting, on examination, a considerable amount of dark carbonaceous matter not carbonized.

A new system of manufacture recently introduced by the Ynysawdre Coal Company, at their works near Bridgend in Glamorganshire, which promises very satisfactory results, is thus described:—The coal is, in the first instance, reduced to a state of powder, being crushed by suitable apparatus; it is then subjected to a careful washing by which the sulphur is removed. It is now dried, and subsequently in this state charged in the oven and treated in the ordinary way. The increased value of coke made in this manner is considerable. Towards the close of the year 1879 when coke in South Wales averaged about 7s. 6d. per ton at the place of production, coke of the quality above referred to commanded an increased price of 3s. per ton, or 10s. 6d. per ton, compared with the price of coke made in the

* "Ure's Dictionary of Arts, Manufactures, and Mines," vol. iv., p. 262.

ordinary way. Since the date referred to the demand for coke has greatly increased, and prices have also risen.

The waste of valuable products in the manufacture of coke has received considerable attention. Dr. Angus Smith, in his report for the years 1877 and 1878 as inspector under "The Alkali Act," calls attention to some important facts:—In the combustion of every ton of coal made into coke 20 lbs. of ammonia are given off and allowed to go to waste. The products of distillation of coal are daily becoming more valuable, and the amount of ammonia and tar destroyed in manufacturing coke is very great, equal to 36,000 tons of the first from 15,000,000 tons of coal, used in the year 1876, for iron only. Or 139,764 tons of sulphate of ammonia, which is sometimes worth £20 per ton, or £2,795,280, a sum which is certainly enormous. In addition to this, the tar allowed to go to waste in the same way, amounts to half that sum, which swells the annual loss to the enormous sum of more than three and a half millions sterling. The loss does not stop here; for as Dr. A. Smith proceeds to show, ammonia being a valuable fertilizing substance, it follows that if the amount wasted, as above noted, were saved and properly applied the yield would be much increased.

Dr. Angus Smith * gives in his last report an interesting and detailed account of the manufacture of coke at Bességes, in France, where coke-burning is practised on a very extensive scale, and the gases evolved in the process utilized, showing that the saving of these valuable elements is practicable. He further adds that "if it were found convenient to adopt for this country the *Bességes* method of making coke, the makers of it would obtain a gross income from the sulphate of ammonia and tar of £1,680,000; taking the amount of coal made into coke to be equal to fifteen million tons per annum and taking the Bességes calculation of expense. This is about 2*s*. 4*d*. per ton for every ton of coal, with the tar, which is nearly the half, or £875,000."

In an agricultural point of view the advantages to be secured are of vast importance, as shown by Dr. A. Smith, who conclusively shows that if the amount of the valuable products wasted were properly applied, it would yield an increase of crops equal

* Fourteenth and Fifteenth Annual Reports of the Inspector. Alkali Acts. Manufacture of Coke, p. 48. Translated from the French by F. Tourget.

to eight million pounds sterling at least. Beyond this the valuable and beautiful products from tar have a great effect on many of the arts.

In Bességes the gas is used for heating the coal; if this gas were saved for burning, a little more coal would be required, but gas may be sold at a much higher price than coal. If, then, the Bességes method were connected with gas-making we should have an enormous amount of saving, besides the amount of gain, and I scarcely dare to venture further in the calculations, but it is certain that some millions more must be added to the already large sum.

Production of the Coal-field.—The data existing on this subject before the present century is scanty and incomplete, the only reliable statistics met with being a return showing the quantity of coal brought into the port of London from the South Wales coal-field in each of the years between 1745 and 1765,* of which the annexed statement is a summary:—

Year.	Quantity.	Year.	Quantity.
	Tons.		Tons.
1745	1,857	1756	3,726
1746	1,636	1757	4,310
1747	2,655	1758	2,289
1748	1,935	1759	1,950
1749	2,859	1760	3,422
1750	2,596	1761	2,774
1751	2,467	1762	2,865
1753	2,973	1763	4,400
1754	3,862	1764	3,373
1755	2,827	1765	4,003

The principal ports of shipment in South Wales at this period were Milford, Tenby, Haverfordwest and Caermarthen, from whence the great bulk was shipped; while from Swansea, Neath and Llanelly, during the whole period, the shipments did not exceed in the aggregate 1,300 tons.

Although much information exists showing the distribution of coal sent coast-wise and exported half a century since, yet returns of production are wanting. Not until the year 1854, when the "Mineral Statistics," including the yield of our coal-fields and make of pig-iron was published, does any reliable information appear. In the volume referred to, the output of the collieries of

* Coal Commission Report, vol. iii., Statistics, p. 22.

the South Wales Coal-field is given as 8,500,000 tons, of which quantity 1,000,000 tons was anthracite and 7,500,000 bituminous and free-burning coal. From 1855 till the year 1859 the returns of production were as follows, distinguishing the anthracite from the bituminous coal, and to this is appended the number of collieries in the South Wales Coal-field in each of those years, including the output of the Monmouthshire collieries, which in later years are separately given:—

Year.	Collieries.	Anthracite.	Bituminium.	Total, South Wales.
	Nos.	Tons.	Tons.	Tons.
1855	245	997,500	7,552,770	8,550,270
1856	304	964,500	7,954,600	8,919,100
1857	325	960,500	6,171,804	7,132,304
1858	352	737,590	6,757,699	7,495,289
1859	388	800,000	8,800,350	9,600,350

The total production of coal in the United Kingdom in the year 1855 was 64,453,079 tons, increased in the year 1859 to 71,979,765 tons, showing an increase in five years of 7,526,686 tons.

Later returns distinguish the output of the collieries in Monmouthshire from those situated in the rest of the coal-field, and throw considerable light on the coal resources of the district. Thus, in the following years, the production increased as under: *—

Divisions of Coal-field.	1860.	1861.	1862.
	Tons.	Tons.	Tons.
Monmouthshire . .	3,800,750	4,650,000	} 3,750,000
Glamorganshire, Eastern Edge	} 200,000	325,000	
Glamorganshire—			
Aberdare District .	1,754,813	1,790,771	2,214,455
Merthyr District . .	850,000	925,000	975,000
South Crop, &c. .	1,800,000	1,875,000	2,100,000
Pembrokeshire . . .	} 1,850,000	2,100,000	1,250,000
Carmarthenshire . .			
Total .	10,255,563	9,665,771	10,289,455

Following the course of production, there appears some interesting detailed statements for the next three years of the output in the following districts, in which the quantities raised

* Coal Commission Report, vol. iii., p. 132.

in Monmouthshire are separately given. Thus, in the year 1863, Monmouthshire contributed 4,075,000 tons, the rest of the South Wales Coal-field, 6,917,081 tons; of which latter quantity the annexed statement gives the quantities, the first four items being the respective returns of parishes in Glamorganshire:—

DISTRICTS.	TONS.
Merthyr (Parish)	812,778
Gelligaer ,,	639,055
Aberdare ,,	2,148,960
Llanwonno ,,	293,288
Rhondda Valley	328,000
Lower end of Taff Vale and Llantwit Vardre	141,000
South Outcrop to Neath	655,000
Neath and Vale of Neath	305,000
Swansea and Swansea Valley	517,000
Glyncorrwg	36,000
Pembrokeshire and Caermarthenshire	1,041,000
	6,917,081
Monmouthshire	4,075,000
Total of South Wales Coal-field	10,992,081

Passing to subsequent years, the annexed summary displays the number of collieries and the output of coal:—

Year.	SOUTH WALES.		MONMOUTHSHIRE.		Total.
	Collieries.	Coal.	Collieries.	Coal.	
	Nos.	Tons.	Nos.	Tons.	Tons.
1864	316	6,948,000	102	4,028,500	10,976,500
1865	322	8,531,336	104	4,125,000	12,656,336
1866	332	9,376,443	100	4,445,000	13,821,443
1867	329	9,092,300	92	4,659,500	13,751,800
1868	298	8,959,500	92	4,250,500	13,219,000
1869	315	9,179,650	73	4,275,150	13,454,800
1870	328	9,299,770	75	4,364,342	13,664,112
1871	299	9,120,000	74	4,915,525	14,035,525
1872	284	10,131,000	85	*...	...
1873	423	9,841,523	118†	4,500,000	14,341,523
1874	371	10,184,885	119†	5,038,820	15,223,705
1875	415	10,632,597	91	3,525,975	14,158,572
1876	400	11,973,336	134†	4,499,985	16,473,321
1877	325	12,634,335	116	4,350,785	16,885,120
1878	329	12,926,225	131	4,490,290	17,416,515
1879	325	13,126,397	129	4,640,340	17,766,737
1880‡	370	16,126,031	166	5,039,549	21,165,580

* Including the output of those collieries in Brecknockshire and on the edge of Glamorganshire.

† Included in another district. ‡ Reports H. M. Inspectors of Mines, 1880.

This will be a fitting place to note the development of the South Wales Coal-field, as shown in the parish returns, compiled annually by the parochial authorities for purposes of assessment, in Glamorganshire. These returns form but a part of the coal raised, but the steady increase appearing year after year is a good index to the output of the collieries. Formerly returns were published by five parishes, but the annexed schedule shows the annual yield in the parishes named (in tons of 2,520 lbs. each) :—

Year.	Aberdare.	Gelligaer.	Llanwonno.	Ystradyfodwg.
	Tons.	Tons.	Tons.	Tons.
1844	176,953	...	11,830	...
1847	269,116	...	44,500	...
1850	477,208	...	42,880	...
1855	1,203,847	...	99,873	...
1860	1,754,813	716,156	110,220	...
1862	2,214,455	591,468	289,820	...
1864	2,048,472	764,521	...	428,489
1866	2,185,571	866,895	395,091	649,828
1868	2,053,509	807,424	361,921	981,787
1870	2,070,920	909,911	415,536	1,332,059
1871	1,836,954	962,946	346,825	1,325,037
1872	2,013,718	1,067,959	395,594	1,555,853
1873	2,054,879	1,078,347	425,731	1,940,566
1874	1,963,141	1,227,477	436,081	1,947,936
1875	1,612,428	916,695	336,463	1,951,606
1876	1,832,981	1,333,819	436,177	2,370,359
1877	1,645,906	1,284,489	533,425	2,492,867
1878	1,653,157	1,234,653	790,645	2,922,234
1879	1,682,033	1,268,429	969,551	3,019,568
1880	1,832,002	1,388,620	1,231,573	3,547,239

Regarding the great depths from which coal is now won in South Wales, some interesting particulars on the subject of deep winning, in connection with the Harris Navigation pits, situated near Quaker's Yard, Glamorganshire, the deepest in the district, have recently appeared, by Messrs. Thomas Forster Brown and George Frederick Adams, MM. Inst. C.E., who are professionally connected with the operations.*

"The depth of the lowest seam at present sunk to was 760 yards; the pits were each 17 feet in diameter inside the walling. In addition to the depth, a special feature was the thickness of hard and heavily-watered rock penetrated. Guide ropes, upon

* Paper read at the Institute of Civil Engineers on the 18th of January, 1881.

the Galloway principle, were used in sinking, and the value of this system was shown in the saving of over two minutes in steadying the bowk at the bottom of the pit at depths of 475 and 530 yards, the total time occupied in clearance at the latter depth being three minutes twenty-six seconds. The method of dealing with the various feeders of water during sinking was described: one of the pits was drained by a hole bored by the diamond machine, which was put down, at a depth of 175 yards from the surface, for a farther depth of 860 feet. Where the strata were conformable, and cut up by faults which intersected all the measures, considerable objection existed to metal tubbing, even for comparatively shallow depths; for the water could rarely be prevented from forcing its way through fissures into the underlying strata. Moreover, provision had to be made for the probable working of the Brithdir seam, a very watery measure, lying at a depth of 250 yards. On account of these and other circumstances, it was ultimately decided to provide for the permanent pumping of all the feeders, and a powerful 100 inch Cornish pumping engine was erected. The parallel motion for the main pump rods was obtained by a gudgeon, attached to the top rods carrying two slide blocks, which worked in cast-iron guides 13 feet long and 27 inches wide. This gudgeon was attached to the beam by two hammered iron radius-rods, 43 feet long, 10 inches wide, and tapering from 3 inches thick at the top and bottom to 1½ inch at the middle. The space between the rods was filled with pitch pine 12 inches thick at the top and bottom and 18 inches wide in the middle. Five lifts, three of which were 26 inches in diameter, and the others 22 inches and 21½ inches, were worked by the Cornish engine. The total feeders amounted to 440 gallons, of which 298 were pumped from a depth of 467 yards. The rods were double, of pitch pine, 16 inches square. To economise space in the pit, the lifts were fixed in one perpendicular line; to effect this the rods directly above the plunger and the rods below were connected by side-rods and distance pieces; the horizontal connecting pipe of the H-piece being cast semi-circular to allow the rods to pass down in a straight line. The total weight of rods, &c., amounted to 181½ tons, that of the water being 133 tons; 35 tons of the difference were counterbalanced by a balance beam in the pit, leaving 13½ tons to overcome friction.

"A large diamond boring machine was used for a portion of the

sinking. The apparatus weighed 10 tons, and consisted of four beams, or transoms, fixed to a centre piece; on the transoms were placed the drills—ten in number—which could be moved to any part of, or inclined to any angle parallel with, the face of the transoms, and each drill could be started or stopped singly. In making the first trials, thirty to forty short holes, at varying angles, and from 3 feet to 5 feet in depth, were bored, the operation requiring twelve to fourteen hours. Nearly one-half of this time was occupied in jacking the machine for the various positions required to bore the sumping holes, bench holes to sump, and finally the cropping holes. Long holes from 15 feet to 30 feet in depth were subsequently tried, and blasted in sections; but having to be bored vertically, so as not to pass out of the line of the shaft, they had not always the most effectual lifting power. Better progress was made with single drills, but the cost of diamonds became too great for the frequent holes and changes, and the contracting company completed their contract by means of a percussive drill, designed by Colonel Beaumont. 'Ingersoll' drills were afterwards used; these had a diameter of 3¼ inches, and a stroke of 4½ inches, and gave excellent results; the only difficulty experienced being in the wear and tear of the tappets, which, when they broke, generally caused damage in the cylinder.

"In hard and wet rock dynamite was found to be a much more effective explosive than gunpowder, requiring about half the number of holes, and saving tamping. In shale, without water, powder was more effective, dynamite being more rapid in its action. In sinking through three yards of dry Pennant rock, the cost of powder and dynamite was, respectively, £12 1*s*. 3*d*. and £10 1*s*. 8*d*.

"Under the circumstances which attended this sinking in hard and wet rocks, 3 yards were considered good progress by hand, and 4½ yards by machine per week; but the authors were of opinion that this rate ought to be improved upon with further experience; they had also arrived at the conclusion that the cost of sinking by machine was less than by hand labour. The average rate of sinking, including walling, but exclusive of stoppages, was 3·77 yards per week, there being nearly an equal per centage of hard rock and shale: the actual sinking occupied about one-half the total time, and walling 12 per cent. The south pit, which was the deeper of the two, was commenced in February,

1878, and finished in February, 1879. The average cost per yard of sinking in shale by hand and without pumps, near the bottom of the shaft, was £11 19*s.* 6·8*d.*; with pumps, £13 2*s.* 8·9*d.*; in hard Pennant rock by hand without pumps it was £40 8*s.* 5·4*d.*; with pumps, £44 13*s.* 2·9*d.* In Pennant rock with pumps and three drills the cost was £34 3*s.* The cost of the 18-inch walling without pumps, including the proportion of iron curbs, came to £11 7*s.* 10*d.* per yard in depth, or £1 3*s.* 10*d.* per cubic yard; with pumps, to £1 7*s.* 5*d.* per cubic yard. These averages included all labour, stores, coal, &c."

Messrs. Brown and Adams, in referring to the question of ventilation, allude to a furnace as being probably the most effective means at great depths; but leaving this question for future consideration, they had meantime erected a Schiele Fan fourteen feet three inches in diameter, and capable of producing a current of about 250,000 cubic feet per minute. This had been done after a series of experiments in various districts. They further urge objections to the positive type ventilators, viz., that in the event of obstructions occurring in the air ways, undue pressure might be applied to separation doors, air crossings, &c.; besides which, they caused a vibratory motion, were costly to erect, and the working parts were in some cases liable to get out of repair. Of the closed fans, which it was stated gave slightly better results than open fans, the Guibal and Schiele were the best.

The winding engine in course of construction is designed to raise 2,000 tons of coal in 10 hours of constant drawing; the weight, exclusive of the rope, being 10½ tons, and the velocity of the ascending cage 40 to 45 feet per second. The scroll drum, with a smaller diameter of 18 feet, rising by fourteen coils to 32 feet, was considered the best method of counterbalancing the rope. The cylinders were 4 feet 6 inches in diameter, with 7 feet stroke; they were inverted and placed on cast-iron supports, the drum being fixed below on masonry pillars. The valves were double beat; and for the steam valves Barclay's simple trip expansion gear was used. The rope was a parallel flat rope of the best selected steel, and consisted of 114 No. 11 gauge wires. The calculated breaking strain was 104 tons, and the factor of safety was nine.

The pit frame is described as constructed entirely of wrought-iron; arrangements being also introduced for loading and un-

loading a single decked cage by gravitation of tubs. The empty trams were hoisted about six feet, and made to run down an inclined way to the cage, being stopped and relieved by a system of catches, the cage being so arranged that on landing on the steps the bottom was inclined. In the above deep winning, at the Harris Navigation Pits, the deepest in the district, the shaft pillar is described as having an area of 400 yards square.

Distribution of Coal.—In the eastern part of the South Wales coal-field Newport and Cardiff are the ports 'of shipment. Newport is situated on the river Usk, and this part of the coal-field is traversed and Newport is connected with the Great Western, Eastern Valleys, Western Valleys, and Newport and Brecon Railways, affording ample facilities for the distribution of coal. The dock accommodation is considerable; the docks have an area of nearly twelve acres, and were opened in the year 1858. More recently increased facilities for commerce have been secured by the opening of the Alexandra Dock, with an area of twenty-eight acres, having ample hydraulic machinery for the shipping of coal. In addition to these docks Newport is most favourably situated, possessing an extensive water frontage on the river Usk, by means of which an extensive trade is carried on.

Cardiff is situated on the river Taff, and is connected with all parts of the kingdom by the Great Western, Taff Vale, and Rhymney Railways. The port has the advantage of a magnificent roadstead and extensive docks constructed by the trustees of the Marquis of Bute. Until these docks were constructed the only outlet for the minerals of this district, of which Merthyr is the capital, was the Glamorganshire Canal, the access to which was very imperfect and the dimensions wholly inadequate for the rapidly increasing trade of this great coal and iron district. It is interesting to trace the early incidents connected with the Bute Docks. They may be briefly stated as follows:—"The Marquis of Bute was the owner of a large tract of land that intervened between the town and the sea, called 'Cardiff Moors,' and conceived the idea of converting it into a harbour on a scale commensurate with the prospective wants of the neighbourhood. In the year 1830 he obtained an Act for constructing a new port, the 'Bute Ship Canal,' and steadily proceeded amidst many difficulties to carry out the design at his individual cost." The work, which was considered a wild speculation, commenced in 1834 with the con-

struction of a feeder from the river Taff. The first stone of the docks was laid in March, 1837, and the docks opened in October, 1839. A few years previously the high character of the coal-seams in the Aberdare and Merthyr districts attracted attention from their valuable qualities as a steam coal, and a great impetus was given to their development by the opening of the West Bute Dock in 1839, and the East Bute Dock in 1859. It may be briefly stated that the West Bute Dock contains a water area of 18 acres; the East Bute Dock an area of 42 acres, with a basin area of 3 acres. Beyond this the Port of Cardiff possesses greatly increased accommodation in late years by the addition of the Penarth Dock and Tidal Harbour, the former having a dock area of 18 acres and a basin of 3 acres, while the latter has a total length of 13,200 feet. This great area has been further supplemented by the New Bute Basin, with an area of 12 acres, with machinery capable of shipping 4,480 tons of coal per day; and the Glamorganshire Canal Dock, with a length of upwards of 5,000 feet, for discharging and loading small vessels, and beyond which increased accommodation has recently been added by the addition of a new dock on the east side of the existing East Dock, with a water area of 55 acres.

Previous to the opening of the Taff Vale Railway in the year 1840, coal was conveyed down the Glamorganshire Canal already referred to, which has a length of 25 miles, with a rise of 611 feet. This great undertaking commenced in the year 1791, and was completed and opened in the year 1794 to Cardiff. The only information showing the extent of mineral traffic on this canal is found in Mr. Jellinger Symons' "Industrial Capacities of South Wales,"* from which it appears that in the year 1846 the coal carried amounted to 287,271 tons, and in each of the years between 1846 and 1852 to the following quantities:—

Year.	Coal Carried.	Year.	Coal Carried.
	Tons.		Tons.
1847	262,077	1850	268,361
1848	281,967	1851	294,537
1849	245,785	1852	301,829

The other principal ports of shipment in South Wales for the export of coal are those of Swansea, Llanelly, and Milford. The

* Published by R. Mason, Tenby, 1855, p. 22.

growth of the port of Swansea has been very rapid; it has been remarked that of all the ports in the Bristol Channel, "there are none more favourably situated than Swansea; for it is an important fact, that Swansea Harbour is accessible to any stranger that may arrive in the bay when blowing too strong for pilots to get off." The stone piers enclosing the outer harbour were erected under an Act passed in the year 1791, and stretch some 600 yards on the east, and 300 yards on the west side.

The following are some of the particulars of the dock accommodation:—The North Docks were commenced in the year 1849 and completed in the year 1861, and possess an area of lock and half-tide basin of 13¾ acres. The South Docks were completed in 1859, the area of the entrance basin being 3 acres, and the dock area 13 acres. Ample provision is here made for shipping coal, large iron boxes, with false bottoms, being employed, each containing 2½ tons, and four of which are conveyed upon a truck each journey; beyond these ordinary tipping-waggons are used.

Llanelly is situated some 10 miles to the west of Swansea, and both ports are the seats of some of the most extensive and important metallurgical works in the kingdom; more especially for the smelting of copper ore, the manufacture of tin-plate, and the reduction of the ores of iron, &c. The port has good docks, is situated on the estuary of the Burry and Llwchwr rivers on the east of Caermarthen Bay, and is connected with the Llanelly and the Great Western Railways. The principal coal shipped at Llanelly is anthracite; which variety of coal is also shipped at Burry Port and Kidwelly, smaller ports to the west of Llanelly.

Milford was formerly a great outlet of the coal of Pembrokeshire; the trade has of late years moved eastward, but is still of considerable importance. The ports of Milford and Pembroke, situated at the mouth of the Dancleddaw river, which here flows into an inlet of the Atlantic, constituting one of the finest harbours in the world, and giving rise to an important naval arsenal. It is here that the South Wales section of the Great Western Railway terminates, the port having extensive commercial relations with the south of Ireland.

With the foregoing brief reference to the more important ports contributing to the distribution, coastwise and to foreign countries, of coal the produce of South Wales, the following statistics will show the growth of the coal-trade. The earliest

accessible returns are for Swansea, where the shipments coastwise, to foreign countries and Ireland, were as follows in each of the years :—

Year.	Coastwise.	Exported.	Total.
	Tons.	Tons.	Tons.
1816	159,181	29,974	189,155
1817	167,251	57,784	225,035
1818	190,022	34,321	224,343

The Cardiff and Newport shipments in each of the same years of coal, the produce of the South Wales coal-field, were as follows :—

Year.	Coastwise.	Exported.	Total.
	Tons.	Tons.	Tons.
1816	177,044	75,199	252,243
1817	207,753	90,090	297,843
1818	218,800	95,414	314,214

In subsequent years the returns of each port are separately distinguished.

The Llanelly and Pembroke shipments in each of the same years stood thus :—

Year.	LLANELLY.		Total.	PEMBROKE.		Total.
	Coastwise.	Exported.		Coastwise.	Exported.	
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1816	29,418	15,480	44,898	27,532	271	27,803
1817	38,512	26,527	65,039	21,956	3,333	25,289
1818	34,570	18,427	52,997	28,970	3,462	32,432

The total shipments from Milford during the same years amounted to but 1,895 tons.

Summarising the above returns, the total quantities of coal and anthracite sent coastwise and exported in each of the above years appear thus, and afford reliable data for comparison :—

Year.	Coastwise.	Exported.	Total.
	Tons.	Tons.	Tons.
1816	393,175	120,924	514,119
1817	435,472	177,734	613,206
1818	472,362	151,624	623,986

From these totals, compared with the total exports previous to the year 1800, when Swansea was the chief port of export, may be gathered some interesting facts bearing on the growth of the coal industries of South Wales. It only remains to add that, during the same years, from 1780 to 1799, the total exports from Cardiff, Llanelly, and Pembroke did not exceed 3,700 tons:— *

Year.	Swansea.	Year.	Swansea.
	Tons.		Tons.
1780	64,502	1790	157,588
1781	53,772	1791	154,943
1782	71,597	1792	179,595
1783	70,725	1793	218,060
1784	102,391	1794	169,999
1785	88,624	1795	182,746
1786	90,645	1796	181,213
1787	98,111	1797	202,023
1788	101,412	1798	211,172
1789	113,509	1799	244,976

In the above quantities are included the coal sent coastwise, which formed the great bulk, the quantities at this period sent to foreign countries not exceeding from 30,000 to 40,000 tons per annum; while in the three years above referred to, the coal sent coastwise, and shipped to Ireland and foreign countries, amounted to:—

Year.	Coastwise.	Ireland and Foreign Countries.	Total.
	Tons.	Tons.	Tons.
1816	4,145,909	824,536	4,970,445
1817	4,067,722	873,806	4,941,528
1818	4,253,007	821,329	5,074,336

Ten years later it is stated on the authority of the author of "Fossil Fuel," that upwards of 64,000 tons of "Stone coal or Culm," were exported from Swansea; while in 1829 Swansea, Newport and Neath, shipped 550,000 tons of coal, and Cardiff 60,000 tons; these quantities presumably included that sent coastwise. For a few years about this period the details bearing on the distribution of coal raised in the South Wales coal-field are somewhat uncertain; in the year 1830 and in subsequent years, returns made by the Commissioners of H.M.

* Coal Commission Report, vol. iii., Appendix, p. 6.

Customs to Parliament, afford all the necessary information bearing on the distribution of our coal, whether to our Colonies, foreign countries, or that sent coastwise to other ports in the United Kingdom, and in late years the coals shipped to Ireland. From the returns above referred to the following details appear for the years named :—

COAL, CINDERS, AND CULM EXPORTED FROM THE UNITED KINGDOM.

Ports.	1830.	1831.	1832.	1833.
	Tons.	Tons.	Tons.	Tons.
Cardiff . . .	711	726	1,052	1,521
Newport. . .	1,930	4,698	5,244	2,609
Llanelly . . .	3,855	5,817	4,740	7,109
Swansea. . .	6,403	7,013	8,198	13,501
Milford . . .	10	...	214	...
Total . .	12,909	18,254	19,448	24,740

In each of the same years the total quantities exported stood as follows, together with the amount of duties received thereon. The duties in the year 1830 varying from 1*s.* per ton to British possessions and 5*s.* 9*d.* per ton in British ships to foreign countries, while in other ships it amounted to 10*s.* In the year 1835 all duties on coal to British possessions were remitted. The remaining duties, a few years later, were reduced, and finally abolished in the year 1850, since which year all coals have been exported free of duty :—

Year.	Quantities Exported.	Amount of Duty Received.
	Tons.	£ *s.* *d.*
1830	504,419	63,889 17 6
1831	510,831	55,237 5 10
1832	588,446	56,706 2 10
1833	634,448	65,008 8 6
1834	615,255	...
1835	736,060	...

From this time forward ample details from Parliamentary and other returns are accessible, showing the distribution of coal, from which the following figures are gathered. In the annexed table appears the quantities of coal, culm, and cinders sent coastwise and exported from the ports of South Wales, including Monmouthshire, in each of the years named since 1834 :—

Year.	Coastwise.	Exported.	Total.
	Tons.	Tons.	Tons.
1834	1,026,838	30,404	1,572,242
1836	1,066,261	46,110	1,112,371
1838	1,227,083	65,902	1,292,985
1840	1,374,419	63,867	1,438,286
1842	1,453,154	109,819	1,562,973
1845	1,656,963	236,061	1,893,024
1848	1,663,937	300,189	1,964,126
1851	1,573,773	453,125	2,126,898
1854	1,786,878	772,481	2,559,359
1857	2,004,225	1,418,026	3,422,251
1860	2,238,875	1,719,560	3,958,436
1863	2,231,071	2,272,540	4,503,611
1866	2,432,654	2,971,920	5,404,574
1869	2,511,080	3,226,790	5,737,870
1872	2,555,805	3,592,767	6,148,573
1873	2,492,404	3,348,147	5,540,551
1874	2,270,512	3,992,316	6,262,818
1875	2,182,535	3,696,724	5,879,259
1876	2,390,402	5,092,392	7,482,792
1877	2,376,466	5,283,417	7,659,883
1878	2,415,667	5,798,565	8,214,232
1879	2,538,179	6,291,337	8,809,516
1880	2,492,204	6,893,839	9,386,043

The great development of the coal industries of the South Wales coal-field is well shown in the above table, more especially when comparing the returns of the year 1850 (when the export duty on coal was repealed,) with those of the year 1860. The coal sent coastwise, although showing a considerable increase, bears no proportion to the yearly increasing quantities exported. In the annexed statement for the years 1860, 1879, and 1880 appear the respective shipping ports and quantities of coal sent coastwise and exported to foreign countries in each of those years from the ports named:—

Ports.	1860.		1879.		1880.	
	Coastwise.	Exported.	Coastwise.	Exported.	Coastwise.	Exported.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Cardiff . . .	782,002	1,133,086	827,458	4,427,602	864,899	4,991,317
Newport . .	629,206	187,591	983,725	935,556	868,963	1,015,550
Swansea . .	227,675	295,102	251,992	775,301	248,853	688,604
Neath . .	185,310	13,740	..	..	..	..
Llanelly . .	284,170	89,996	116,389	69,740	120,383	75,874
Milford . .	51,351	45	27,153	..	25,168	..
Briton Ferry .	..	..	185,287	53,406	191,573	94,070
Port Talbot. .	61,965	..	79,434	21,272	80,922	16,798
Porth Cawl .	17,196	..	66,741	8,460	91,443	11,626
Total . .	2,238,875	1,719,560	2,538,179	6,291,337	2,492,204	6,893,839

Railway Distribution.—The Taff Vale and Great Western Railways and their many branches contribute mainly to the distribution of the great bulk of coal to the ports of shipment and to remote parts of the kingdom, other lines of railways contributing in a lesser degree. The Taff Vale main line, extending from Merthyr Tydvil to Cardiff, was opened in October, 1840, and completed in April of the following year; originally it had but a single line of rails, which were far from sufficient for the traffic, and soon double rails were laid down. The detailed returns of mineral traffic published annually, leave nothing to be desired as regards the statistics of coal conveyed over the main line and branches, which had increased enormously during the forty years the railway has been in existence, and may be gathered from the annexed figures taken from the Company's return of coal and coke carried by all trains in each of the years given:—

Year.	Tons.	Year.	Tons.
1841	41,669	1871	3,593,932
1844	187,740	1872	4,213,506
1847	360,324	1873	4,527,641
1850	594,222	1874	4,352,778
1853	874,362	1875	3,776,813
1856	1,394,394	1876	4,879,180
1859	1,759,422	1877	5,170,953
1862	2,540,657	1878	5,613,639
1865	2,855,198	1879	5,849,184
1868	3,540,324	1880	6,894,403

Of the aggregate quantities, the following table, prepared from the railway return previously referred to, shows the quantities carried in each of the years to the places named:—

Distribution.	1847.	1865.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.
Cardiff and Penarth Junction	336,769	2,501,689	4,761,254	5,064,111	5,955,457
Sold retail	23,555	212,075	327,506	294,556	356,691
Quaker's Yard Junction .	..	102,611	90,664	121,405	135,419
Mountain Ash Junction . .	..	37,024	17,903	10,160	4,006
Conveyed over by other Railways . .	...	1,799	413,781	352,329	345,757
Brecon and Merthyr Junction	..	..	254	5,916	97,010
Walnut Tree Bridge Junction	..	..	2,277	707	63
Total	360,324	2,855,198	5,613,639	5,849,184	6,894,403

The Great Western Railway passes through the entire length

of the coal-field, and like the Taff Vale exercises a great influence in the distribution of the coal. The Great Western carrying it inland, not only to remote parts of the kingdom but also to the Metropolis. An early return for the year 1857, when the traffic originated, gives the quantity carried from South Wales as 120,080 tons; in 1865 the Midland Railway conveyed 1,983 tons from the coal-field, advancing to the year 1866, when the railway returns assume a definite form, the distribution is traced with much clearness, the quantities in each year appearing as follows:—

Year.	Great Western.	Midland.	Monmouthshire and Canal.	Vale of Neath.	London and North-Western.
	Tons.	Tons.	Tons.	Tons.	Tons.
1865	1,345,512	...	1,315,783	700,592	37,670
1867	2,238,342	1,637	1,579,410	911,600	...
1868	2,553,487	573	1,389,660	1,046,432	47,648
1869	2,800,790	390	1,528,354	1,106,064	71,415
1870	2,850,412	4,730	1,676,486	*	70,321
1872	3,067,685	27,351	1,759,356	*	107,520
1874	3,427,576	191,027	2,120,700	*	439,493
1876	4,445,775	570,120	*	*	750,524
1878	4,422,464	591,333	*	*	758,790
1879	4,763,429	639,553	*	*	827,831
1880	5,384,411†	707,458	*	*	903,335

It is only necessary to add that details of the distribution of the above quantities will be found in the "Mineral Statistics of the United Kingdom" and vol. iii. of the "Coal Commission Report, 1871."

Prices of Coal and Cost of Production.—An inquiry instituted about the year 1860 shows that at that period the cost of cutting coals and filling into trams varies, according to the district, from 10*d.* to 2*s.* 6*d.* per ton. These extreme variations are due to the thickness of the seam and to its quality top and bottom. The cost at bank, including royalties and all expenses, but not interest on capital expended, being about 5*s.* 6*d.* per ton. At this period, 1860, the selling price of coal at pit's bank, subject to variation, being, on the average, as follows:—

* Included in the Great Western return.

† Beyond this quantity in the year 1880 the Great Western Railway carried 2,696,610 tons of coal from Monmouthshire.

SOUTH WALES.	s.	d.
Large coal	6	6
Brush coal (*i.e.*, coal cut and sold thorough and thorough as it is in the seam)	5	6
Clean small coal	4	6

These rates also apply to Monmouthshire.

Railway charges, according to old Acts of Parliament, were as follows about the year 1860:—

	s.	d.	
For tonnage (*i.e.*, the use of the road) .	0	1	per ton per mile.
For locomotive power	0	0½	,, ,,

These rates have been considerably reduced in recent years. The average distance of the South Wales collieries from the ports of shipment may be taken at about 18 miles, and the cost of shipping at port, per ton, 6*d*. In the year 1860 the cost of Welsh coal, at port, will have been about:—

	s.	d.	
Getting coal	5	6	per ton.
Conveyance to ports and waggons	1	10	,,
Shipping	0	6	,,
Total	7	10	,,

During the next ten years, till 1870, the wages of coal-miners were but moderate; in the following year, 1871, a period of prosperity set in, when the iron-workers sought an increase of wages, this was succeeded by the coal-miners seeking corresponding advantages. On the average, at this period, the collier worked four days per week, receiving 40*s*. per week, or 10*s*. per day. Between 1872—74 the great strike occurred in South Wales, when it may be remembered about 60,000 out of 65,000 hands engaged in the collieries and ironworks of the district struck work from the 1st December, 1872, to the middle of February, 1873, causing the stoppage of 118 collieries.

The loss of production in the interval referred to has been estimated at 1,170,000 tons of coal; the total cost of the strike to the masters and men at about £2,000,000; the loss of wages alone amounting to about £800,000.

Towards the close of the year 1873 the tide of prosperity turned, prices fell and wages decreased, till in 1877 colliers' wages in South Wales did not exceed from 4*s*. to 4*s*. 6*d*. per day for ordinary pitmen, and 5*s*. to 5*s*. 3*d*. for hewers, since

which date wages have continued to decrease. The disastrous strike of 1877 at Saundersfoot, in Pembrokeshire, is another example of loss to industry. Here a cessation of labour continued for seven months, the colliers eventually resuming labour on the former terms.

The average price of coal prevailing in the year 1878 was 8*s*. per ton; the highest price, 10*s*. per ton, and the lowest, 6*s*. 6*d*. per ton. While in 1879 the average price did not exceed 7*s*. 3*d*. per ton; the highest price, 11*s*. per ton, and the lowest, 6*s*. per ton, compared with 7*s*. 6*d*., 13*s*., and 6*s*. in the year 1880.

Population employed in Coal and Iron-mining in the South Wales Coal-field.—The number of male persons employed in coal-mining operations in South Wales in the year 1854 was 32,473; the number in ironstone-mining, 10,272, thus apportioned to the respective counties of South Wales in which the mineral basin occurs:—

Counties.	Coal Mining.	Iron Mining.
	No.	No.
Glamorganshire . . .	15,295	5,079
Monmouthshire . . .	11,367	3,404
Caermarthenshire . . .	3,344	19
Brecknockshire . . .	1,541	1,767
Pembrokeshire . . .	926	3
Total . . .	32,473	10,272

The total number of females employed in coal-mining in South Wales in the same year was 1,059, of whom 395 were employed in the Monmouthshire area of the coal-field.

Referring to the annual reports of H.M. Inspectors of Mines for the year 1873, the total number of persons employed in the South Wales coal-field, exclusive of that part of the coal-field in Monmouthshire, was, in coal-mining, 45,474, of whom 36,316 were employed underground, and 9,158 over ground. The number in ironstone mines being 1,090, of whom 805 were under and 285 above ground.

In subsequent years since 1874, the numbers employed in the South Wales coal-field in coal and ironstone-mining have been as follows, distinguishing those engaged under and above ground and the quantity of coal and ironstone raised, according to the reports of H.M. Inspectors, to which is added, for comparison, the average quantity raised per man in each year:—

Year.	PERSONS EMPLOYED.			Coal Raised.	Ironstone Raised.	Total Coal and Ironstone.	Average per man.
	Above Ground.	Under Ground.	Total.				
				Tons.	Tons.	Tons.	Tons.
1874	13,865	59,463	73,328	16,432,060	363,131	16,785,191	229
1875	11,893	60,750	72,643	14,173,143	398,533	14,571,676	200
1876	10,836	56,647	67,483	16,972,284	223,386	17,195,670	255
1877	10,180	55,126	65,306	16,921,214	214,429	17,135,643	262
1878	9,590	54,146	63,736	17,517,118	196,331	17,713,449	278
1879	10,187	56,308	66,495	17,819,043	143,525	17,962,268	270
1880	10,920	58,238	69,158	21,165,580	148,101	21,318,981	308

The population employed above and below ground in the South Wales coal-field was as follows in the year 1879, distinguishing the number of persons in each county :—

County.	Under Ground.	Above Ground.	Total.
	Persons.	Persons.	Persons.
Brecknockshire . .	438	65	503
Glamorganshire . .	39,843	7,238	47,081
Caermarthenshire .	1,964	542	2,506
Pembrokeshire . .	424	182	606
Monmouthshire . .	13,639	2,160	15,799
Total . . .	56,308	10,187*	66,495

Resources and Probable Duration of the South Wales Coal-field.—From the Report of the Royal Coal Commission the total quantity of coal ascertained by Messrs. H. Hussey-Vivian and George T. Clarke as remaining in this great coal-field was 36,566,195,917 tons; of this quantity the amount existing to depths not exceeding 4,000 feet is given as 32,456,208,913 tons, that existing at depths exceeding 4,000 feet amounting to 4,109,987,004 tons. An analysis of the Report of the Royal Coal Commission distinguishes the net quantity of coal remaining unwrought in the several divisions of the coal-field as follows :—

SOUTH WALES MINERAL BASIN.†

	TONS.
Pembrokeshire	215,695,910
Eastern division of coal field to the Glyncorrwg Fault on the west	12,963,230,517
Division of coal-field westward of the Glyncorrwg Fault	23,387,269,490
Total quantity of unworked coal in coal-field	36,566,195,917

* Of this number 990 were females, of whom 558 were above 16 years and 432 under that age.

† Coal Commission Report, vol. i., pp. 7, 8, and 15.

At the rate of production in the year 1870, namely, 13,664,112 tons, this coal-field would furnish supplies for 2,676 years. Since the year 1870 the output of the collieries has largely increased, amounting in the year 1879 to 17,819,043 tons, and in 1880 to 21,165,580 tons, apportioned as follows:—

COUNTY.	COAL RAISED. Tons.
Brecknockshire	100,616
Glamorganshire	15,320,096
Caermarthenshire	625,933
Pembrokeshire	79,386
Monmouthshire	5,039,549
Total	21,165,580

The output of 1880 exceeding that of 1879 by 3,346,537 tons, equivalent to upwards of 18 per cent.

The total production in the ten years ending 1879 was 154,162,130 tons; this quantity, deducted from the original estimate, would leave 36,412,033,787 tons available for future use, which at the average consumption of the past ten years (15,416,213 tons,) would yield supplies for 2,362 years; and at the rate of production in 1880 the exhaustion of the South Wales coal-field would take place 1,720 years hence.

CHAPTER XV.

GLOUCESTERSHIRE COAL-FIELD.

Description of Coal-field—Section of Strata—Area of Woods and Plantations in Forest, and Ancient Rights of Miners—Analyses of Coal—Production and Distribution by Railway and by Ship—Price of Coal—Population employed in Coal and Iron Mining—Resources and probable Duration of Coal-field.

Gloucestershire Coal-field.—*Forest of Dean.*—The coal-field bearing this name occupies a superficial area of 34 square miles; it is distant some 14 miles from the city of Gloucester, and lies between the rivers Severn and Wye. In form and outline this basin is more perfect than any other coal-field in Great Britain. The coal measures, in their greatest section, are no less than 2,765 feet, and the uniform dip of the strata, from the margin of the coal-field towards the centre, is so regular in its occurrence that each division of its strata is well known. In this section occur 15 seams of coal, varying in thickness. Of these seams, exceeding 2 feet thick and upwards, there are eight, giving an aggregate thickness of solid coal of 24 feet. Professor E. Hull, F.R.S., in his "Coal Fields of Great Britain," gives the following section, showing the succession of the coal seams:—

	Ft.	In.
Sandstone and shales, with thin coals	830	0
1. Cow Delf	0	8
Strata	91	10
2. Dog Delf	1	2
Strata	46	9
3. Smith Coal	2	6
Strata	34	6
4. Little Delf	1	8
Strata	48	8
5. Park End High Delf	3	7
Strata	56	0
6. Starkey Delf, with parting	2	0
Strata	50	0
7. Rocky Delf	1	9
Strata	77	6

		Ft.	In.
8.	Upper Churchway Delf, with partings	1	11
	Strata	34	0
9.	Lower Churchway Delf	1	6
	Strata	150	0
10.	Braizley Delf	1	9
	Strata	430	0
11.	Nag's Head or Yorkley Delf	2	9
	Strata	153	0
12.	Whittington Delf	2	6
	Strata	137	0
13.	Coleford High Delf . . . 2 ft. to	5	0
	Strata	124	0
14.	Upper Trenchard Delf	2	0
	Strata	72	0
15.	Lower Trenchard or Bottom Coal	1	4

The thick series of sandstones occurring between the Churchway and Coleford High Delf coal seams yields an excellent building stone, and have given rise to numerous quarries; and Professor Smyth is of opinion that these sandstones appear to be the equivalent of the Pennant of the Bristol coal-field.

The coal measures are surrounded by belts of millstone grit and carboniferous or mountain limestone, upon which they rest, and the carboniferous limestone, in turn, reposes upon a bed of Old Red Sandstone. Sir Henry de la Beche gives the following details in the "Memoirs of the Geological Survey,"* showing the thickness of the several divisions of the strata of this coal-field:—

	Feet.
Coal measures, with fifteen coal seams	2765
Millstone grit	455
Carboniferous limestone	480
Lower limestone shale	165
Old Red Sandstone	8000

Of the 24,000 acres comprising the area of the Forest of Dean, it appears 18,500 acres belong to the Crown, subject to certain rights of the free miners; between 600 and 700 acres belong to the Crown, free from all rights of common, the remaining 4,800 acres being the property of private individuals; the existing woods and plantations in the Forest extend over between 14,000 and 15,000 acres, consisting almost entirely of oak, of ages varying from 2 to 70 years; the greater portion, however, are from 50 to 60 years old, and in general are in a thriving condition. From the report of the Select Committee of the House of Commons, dated July, 1874, are gathered many interesting facts: it is there

* Vol. i., p. 203.

stated that the surface of the Forest occupied by the mines is estimated at 1,000 acres, within which is included spoil banks, quarries, railways, tramways, and other works, while the present income to the Crown from coal mines varies from £11,000 to £12,000 per annum, and from iron mines from £4,000 to £5,000 per annum.

Special privileges are inherited by the male population, that is to say, every male person born and abiding in the hundred of Saint Briavels, of the age of 21 years, who has worked for a year and a day in a coal or an iron mine within the hundred, is entitled to be registered as a free miner. These registered free miners, according to the returns published in the year 1838, numbered 1,200; they are not now so numerous as then, their numbers in the year 1874 probably not exceeding 700 or 800. The privilege possessed by these free miners consists in their being entitled to the exclusive rights of having grants from the Crown of what are called "gales," which confer licenses to work in mines. These "gales" number about 260, in which coal and iron occur, and of this number not less than 55 were in operation in the year 1879 and 63 in the year 1880.

Other deposits of coal occur in the Gloucestershire portion of the Bristol coal-field. A considerable section of the Bristol coal-field belongs to Somersetshire; these will be considered in a succeeding chapter, referring to the East Somerset and Bristol coal-fields.

Analyses of the Forest of Dean Coal.—A reference to the distribution of coal, the produce of the Forest of Dean, for the years 1867, 1868, and 1870, will sufficiently show the extent to which it is employed in the industries of the district and the surrounding neighbourhood. It is extensively used in the ironworks of the Forest, being previously converted into coke. It is also in great demand for household consumption; its hardness, large size, and good burning qualities, rendering it especially suitable for this purpose.

In the Admiralty investigation on the coals suited to the Steam Navy, the coal raised at the Park End Colliery, from the "Park End High Delf," or Lowry Vein, is thus referred to and described. "The vein is generally regular, and about 3 feet thick, and is worked long work, as in the thin veins of the Staffordshire coal-field. The overlying and subjacent strata are of the usual

kind of shale. The dip varies from 6 inches to 2 feet in the yard, or from one in six to two in three." The coal is described to be of a "free burning character, of great strength and durability." The distance from the shipping port of Lydney is 5 miles. The current price in summer is 10*s.* per ton; in winter, 11*s.*, free on board, and the principal markets are in Ireland, Cornwall, Cheltenham, and the manufacturing districts of Gloucestershire and Bridgewater The coal examined had a very hard and compact structure, with a clean and bright fracture, and contained iron pyrites in very large quantities in every joint, even when broken down into the smallest sized pieces. It was remarked during the examination that the coal kindled easily, but that it made a very dirty, smoky fire, which, at the ordinary working draught, caused immense volumes of dense smoke to appear at the chimney top. When the draught was increased, the fire became clearer, but then the rush of smoke swept the loose soot from the flues and chimney, and carried it out in large flakes from the chimney top. If the draught was lessened, the fire would hardly burn, and, on opening the doors, the whole place was instantly filled with the loose ashes, and smoke forced out from the fire. The cinders, ashes, and clinker, were of a light weight, and clean; the clinker contained much scoria, some of it quite vitrified. The Park End seam, above referred to, has the annexed composition:—

RESULTS TABULATED.

Carbon	73·52
Hydrogen	5·69
Nitrogen	2·04
Sulphur	2·27
Oxygen	6·48
Ash	10·00
Total	100·00

The specific gravity of the coal is 1·283; its yield of coke, 57·8 per cent.; the mean weight of a cubic foot, 54·44 lbs., and the economic weight or space occupied by one ton, 41·14 cubic feet.

The Coleford High Delf and Trenchard seams, extensively worked in the Forest, and favourably regarded as serviceable coals, much in request for domestic purposes, the small being used for raising steam, are thus referred to. The Coleford High Delf, worked on the north-western side of Dean Forest, in the

neighbourhood of Symond Yat, on the River Wye, where the seam is 5 feet thick, is thus constituted. Some portions of the seam in the High Meadow district occasionally yield a peculiar character of coal, known locally as "black coal," containing, by analysis, 87 per cent. of carbon. The Trenchard Coal, of which the analysis appears side by side, has a thickness, in the neighbourhood of Lydney, of 4 feet:—

RESULTS TABULATED.

Constituents.	Coleford High Delf.	Trenchard.
Carbon	78·810	80·709
Hydrogen	5·303	5·425
Oxygen	9·055	7·060
Nitrogen	1·750	0·735
Sulphur	2·062	1·271
Ash	3·020	4·800
Total . .	100·000	100·000

Production of Coal.—The earliest information on this subject takes us back to the year 1788, when, of the 131 collieries then existing in the Forest, 90 were in operation, producing 1,816 tons of coal per week, equivalent to an annual production of 94,432 tons. The first railway constructed in the Forest of Dean, and made available for the conveyance of mineral traffic, was about the year 1809, from Newnham to Churchway, a distance of seven and a half miles. A careful search of numerous documents and treatises referring to the Forest of Dean since the year 1788, has not been fruitful of results until the year 1854, when it appears 60 collieries were in active operation, producing 420,866 tons of coal. In subsequent years, as in 1854, the returns of production of coal in the Forest of Dean were included in the total produce of the coal-fields of Gloucestershire, Somersetshire, and the Anthracite and Lignite deposits of Bideford and Bovey Tracey in Devonshire.

The following figures indicate the production of the above-named deposits, as published for the year 1854:—

COAL FIELDS.	TONS.
Gloucestershire, "Forest of Dean"	420,866
Somersetshire, "Bristol Coal Field"	1,050,000
Devonshire, Bovey Tracey Lignite	15,000
,, Bideford Anthracite	6,500
Total	1,492,366

In the year 1855, and until 1867, the returns include the output of the collieries of Gloucestershire, Somersetshire, and Devonshire, and appear as follows:—

Year.	NUMBER OF COLLIERIES.			Production of Coal.
	Gloucestershire.	Somersetshire.	Devonshire.	
				Tons.
1855	55	31	2	1,430,620
1856	56	29	2	1,530,000
1857	62	35	2	1,225,000
1858	59	35	2	1,125,250
1859	60	35	2	1,250,000
1860	63	37	2	*
1861	71	40	2	*
1862	76	42	2	1,750,000
1863	78	41	2	1,950,000
1864	94	37	2	1,950,000
1865	97	37	1	1,875,000
1866	79	35	...	1,850,700
1867	76	34	...	1,975,000

About this period the production of the collieries in Dean Forest is separated, and is shown in the annexed table, with the number of collieries working in each year. The totals in the last column include the production of Somersetshire in each of the years from 1867 to 1873:—

Year.	FOREST OF DEAN.		Total of Gloucestershire.
	Number of Collieries.	Coal Produced.	
		Tons.	Tons.
1867	54	847,667	1,975,000
1868	54	848,128	1,969,000
1869	50	852,125	1,979,000
1870	44	907,183	1,955,950
1871	54	837,893	2,086,475
1872	59	730,409	*
1873	76	790,374	1,858,740
1874	71	666,697	1,147,272
1875	69	702,080	1,273,080
1876	69	668,009	1,257,547
1877	64	638,319	1,194,726
1878	60	655,903	1,147,605
1879	55	779,428	1,250,718
1880	63	759,853	1,195,930†

Since the year 1873, the production of Gloucestershire is dis-

* Included in the Monmouthshire return.
† Return H.M. Inspectors of Mines.

tinguished, and includes the output of the Forest mines; the difference between the two columns in later years will be coal raised in that part of the county belonging to the Bristol district.

For the years 1867 and 1868 the coal raised from the Forest mines is shown in the following statement:—

Workings.	1867.	1868.
	Tons.	Tons.
Galee's return of quantities worked exclusive of colliery consumption and workmen's allowance	777,677	778,828
Consumed by engines	40,000	40,000
Consumed by workmen	30,000	30,000
Total raisings	847,677	848,128

The following are the quantities of coal raised in the several collieries in the Forest of Dean in the year 1880, amounting to 759,853 tons:—

Collieries.	Tons.
Arles Level	2,011
Bailey Hill	5,232
Bilson	4,482
Britannia	33,060
Bridewell	58
Brooming Hold	1,007
Chapel Quarry	1,120
Coalway Hill	120
Coal Pit Hill	362
Cross Knaves	769
Crump Meadow	75,173
Dark Hill	4,206
Deans Meend	3
Farmer's Folly	7,924
Foxes Bridge	126,978
Gentlemen Colliers	3,937
Hopewell Engine	4,331
Haywood	2,344
Hillers Land	80
Hawkin	35
Invention	313
Knockley Sump	684
Lightmoor	60
Little Brockhollands	1,562
Lonk Level	618
Little Britain	297
Lydbrook D. Level	5
Morses Level	139
New Fancy	8,382
New Found Out	2,285
New Road Level	1,154
Old Croft Level	15
Carried forward	288,746

Collieries.	Tons.
Brought forward	288,746
Nagshead	22,089
Old Fire Engine	14
Patches	632
Parkend	8,093
Prosper	34
Princes Royal	2,665
Parkhill	2,565
Pluckpeny	179
Resolution	83,059
Royal Forester	56,976
Rose in Hand	60,961
Regulator No. 4	665
Richard Winter	14,065
Smith's Delight	2,345
Society	763
Speedwell	1,994
Soundwell	41,555
Saint Vincent	1,643
Success	6,670
Speculation	18,694
Small Profit	24,173
Tormentor	1,416
Trafalgar	88,794
Uncertainty	595
Unity	6,331
Vallet's Level	779
Wallsend	8,847
Whirrley	654
Worrall Hill	13,739
Wiemell	50
Well Level	68
Total	759,853

Distribution of Coal.—The principal shipping ports are those of Gloucester and Bristol, from which considerable quantities of coal are sent coastwise and to foreign countries. Previous to the year 1831 an export duty was levied on all coals sent out of the United Kingdom, but in that year the duties levied on coals sent to our British possessions were repealed, and it was not till the year 1850 that the duties levied on coals sent to foreign countries were wholly repealed.

The respective shipments from Bristol and Gloucester were as follows in each of the years given since 1819:—

Year.	Bristol.	Gloucester.	Total.
	Tons.	Tons.	Tons.
1819	3,711	3,485	7,196
1821	2,543	15,615	18,158
1823	4,427	22,799	27,226
1825	4,986	14,077	19,063
1827	6,658	18,591	25,249
1829	6,517	...	6,517
1830	6,517	98	6,615

As already stated, the duty on coal sent to our colonial possessions was repealed in the year 1831. In the two previous years the duties varied from 8*d.* to 1*s.* per ton. At the same period, the duty levied on coals sent to foreign countries was 3*s.* 4*d.* per ton, when conveyed in British ships, and 6*s.* 8*d.* in ships of other countries. While as regards cinders, small coal, and culm, the respective duties were 2*s.* per ton in British ships, and 4*s.* per ton in those of other countries.

The total amount of duties received in the year 1830, on 504,419 tons, was £63,889 17*s.* 6*d.*, and in the year 1832, on 588,446 tons, £56,706 2*s.* 10*d.* During the few years prior to the total abolition of all duties on coal exported, the quantities and duties received were as under:—

Year.	Quantities.	Duty.
	Tons.	£ s. d.
1847	2,483,161	4,195 12 5
1848	2,785,300	4,393 2 10
1849	2,826,039	3,233 13 2
1850	3,351,880	1,045 15 1

In each of the above-named years, the shipments from Bristol

and Gloucester were as follows; the amount of duty does not appear, the sum, however, will have been inconsiderable :—

Year.	Bristol.	Gloucester.	Total.
	Tons.	Tons.	Tons.
1847	10,968	112,202	123,170
1848	11,959	119,993	131,952
1849	15,479	89,272	104,751
1850	13,547	85,707	99,254

In subsequent years the total exports of coal are shown in the following table, the great bulk being sent coastwise to other ports in the United Kingdom :—

Year.	Bristol.	Gloucester.	Total.
	Tons.	Tons.	Tons.
1852	11,050	89,229	100,279
1854	13,425	79,023	92,448
1856	11,662	97,288	108,950
1858	12,084	138,438	150,522
1860	10,897	163,982	174,879
1862	5,791	168,698	174,489
1864	11,196	172,104	183,300
1866	10,944	175,647	186,591
1868	13,228	171,859	185,087
1870	11,854	200,209	212,063
1872	12,437	345,876	358,313
1874	7,353	205,438	212,791
1876	8,959	172,053	181,012
1877	7,146	167,495	174,641
1878	10,121	202,785	212,906
1879	12,110	254,862	266,972
1880	10,731	218,496	229,227

From the above table it will be seen that the greatest exports from Bristol and Gloucester took place in the year 1872, when 358,313 tons were shipped; of this quantity 344,450 tons were shipped coastwise from Gloucester, and 1,426 tons exported to foreign countries, the shipments from Bristol amounting to 12,295 tons. Since 1872 a decline of shipments is shown from the above-named ports, the total in 1880 being but 229,227 tons.

Some interesting details of the distribution of the Dean Forest coal appear for the years 1867, 1868, and 1870, in which the quantities carried out of the district are separately distinguished from that used locally, and in the ironworks of the district. The returns for these years are as follows :—

How Distributed.	1870.	1868.	1867.
	Tons.	Tons.	Tons.
By G. W. Railway from Lydney	16,728	7,617	7,760
From Bullo Pill Railway . .	284,819	306,000	300,000
By water from Lydney . .	171,919	168,404	166,992
By water from Bullo Pill . .	96,307	61,220	59,380
Land sales in the Forest and surrounding districts .	82,000	80,000	82,000
Consumed by engines and workmen . . .	70,000	70,000	70,000
Consumed at iron, tin, and wire works in the Forest .	185,410	154,887	161,545
Totals . . .	907,183	848,128	847,667

The earliest return of coal carried by the Midland Railway from Gloucestershire is for the year 1856, showing that 132,035 tons, compared with 230,745 tons in the year 1866, and 226,643 tons in the year 1867, were carried. The following shows the coal carried from collieries in Gloucestershire since the year 1858:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1858	174,840	1871	234,420
1860	227,265	1872	232,875
1862	223,606	1873	293,069
1863	233,174	1874	225,013
1865	246,625	1875	243,753
1866	230,745	1876	227,740
1867	226,643	1877	200,253
1868	210,138	1878	192,007
1869	215,718	1879	188,542
1870	219,010	1880	223,098

The quantity carried in the year 1880 was 223,098 tons, the total quantities of coal carried by the Midland Railway system the same year, from all districts, giving an aggregate total of 12,383,910 tons.

The Gloucester and Berkley Canal Company are also carriers of coal from the Forest of Dean Collieries. In the year 1873 the total amounted to 1,612 tons, increased to 4,333 tons in 1874, and in the years 1877 and 1880, from Dean Forest and South Wales respectively, 31,262 tons and 14,591 tons.

Price of Coal.—We learn from the "Survey of Gloucestershire," written by Mr. Rudge, that, in the beginning of the

present century, house coal from Dean Forest pits was sold at 7*s.* per ton, and smiths' coal for 5*s.* per ton; much of the coal consumed in the city of Gloucester and the neighbourhood, at that time, being principally supplied from Shropshire and Staffordshire. In the year 1870 prices of coal were as follows:—

COLLIERIES, FOREST OF DEAN.

Hopewell, Coleford, 5*s.* 6*d.* and 6*s.*
Miles Level, Coleford, 3*s.* 6*d.* to 8*s.*
Nelson, Coleford, 5*s.* 6*d.*, 7*s.* and 8*s.*
Pillowell, Lydney, 8*s.* 6*d.*
Royal Forrester, Coleford, 6*s.* and 7*s.*

The above were the average prices per ton at the pit's mouth.

Here, as in other districts, prices have fluctuated since the year 1870. The average prices ruling in 1879 were about 9*s.* 9*d.* per ton for coal (best household), and for slack, 4*s.* 9*d.*, the highest price of coal being 14*s.*, and the lowest 6*s.* 6*d.* per ton; the slack ranging from 3*s.* 6*d.* to 5*s.* per ton. The average price at the pit's mouth in 1880 was about 10*s.*, and slack 4*s.* 6*d.* per ton.

Population Employed.—In the year 1854 the number of persons employed in coal and iron mining, in the Forest of Dean, was 2,218; of these 2,007 were coal, and 211 ironstone miners. Twenty years later the total persons employed amounted to 5,050, of whom 3,962 were engaged under ground, and 1,088 above ground. Since that date Her Majesty's Inspectors of Mines give the numbers engaged as follows, to which is added the produce of coal and the individual output per man:—

Year.	Under Ground.	Above Ground.	Total.	Coal Raised.	Average per Man.
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	3,962	1,088	5,050	671,232	133
1875	3,803	891	4,694	702,053	149
1876	3,573	861	4,433	619,805	139
1877	3,468	680	4,148	627,401	151
1878	3,291	694	3,985	657,275	165
1879	3,677	614	4,291	788,501	180
1880	3,207	623	3,830	720,123	188

These figures refer exclusively to the Forest of Dean coal-field; the population employed in the Bristol district, also in Gloucestershire, will be included in the Somersetshire coal-field.

Of the population employed in 1879 there were 3,305 working under ground above the age of 16, and of those above ground, 581 were above the same age, the remainder being under; while a total absence of female labour appears throughout the Forest of Dean, as well as the Bristol district.

Resources of Coal-field and probable Duration.—The total area of the Forest of Dean coal-field, as recorded by the Royal Coal Commission,* amounts to 302,671 statute acres, one foot thick. Of this area, the portion already wrought amounts to 37,787 statute foot acres, the portion unwrought, deducted for faults, barriers, supports, &c., amounting to 75,681 statute acres, of the same thickness, leaving unwrought, and likely to be clear for working, 189,203 statute foot acres. In this computation, after making due allowance for unavoidable loss and waste in working, each statute acre is estimated to yield 1,400 tons, giving a total quantity of coal yet available (1870) of 265,000,000 tons.

Taking the production of the year 1870, as recorded in the "Mineral Statistics," 907,183 tons, the coal remaining would last for 292 years. Since 1870, however, a diminished production appears, that of 1880 giving but 759,853 tons. The total yield during the past ten years is 7,376,295 tons, giving an average annual output, from the Forest of Dean collieries, of 737,629 tons. Making the necessary deduction, and taking this average, there yet remains available 257,623,705 tons; sufficient to last for a period of about 349 years.

* "Coal Commission Report," vol. i., p. 18, Mr. Joseph Dickinson, H.M. Inspector of Mines.

CHAPTER XVI.

THE BRISTOL COAL-FIELD IN GLOUCESTERSHIRE AND SOMERSETSHIRE.

General description of the Bristol and Radstock Coal Basin—The Clapton-in-Gordano and Severn Basin, and the Nailsea Basin—Succession of Strata—Analyses, Production, and Distribution of Coal—Prices of Coal—Population employed in Coal Mining—Resources and probable Duration of Coal-field.

The Somersetshire and Bristol Coal-field.—Few coal-fields possess more interesting features. The following section gives the succession of rocks and their average thickness:—

		THICKNESS. Feet.
Trias	Rhœtic beds	50
	New Red Marl	300
	Dolomitic Conglomerate	25
Carboniferous system	Coal measures	5,000
	Millstone grit	800
	Carboniferous limestone	3,000
	Lower limestone shales	500
Old Red Sandstone	Old Red Sandstone	4,000

The dolomitic conglomerate reposing on the coal measures, and so called from its peculiar character, contains hematite iron ore deposits; the variable thickness however of this, the lower division of the trias, rarely exceeding from 25 to 30 feet in this area, has rendered mining operations somewhat uncertain, and hence the deposits have been developed but to a limited extent. The coal measures of this district consist generally of a series of shales and sandstones, with seams of coal and occasional measures of ironstones, and may be taken in their average depth as having a thickness of not less than 5,000 feet. These measures are divided into an upper and lower series, between which interposes an arenaceous rock, averaging in thickness about 2,000 feet, and known as the "Pennant Grit," consisting of thick beds of sandstone, varying in colour from grey to dark red. These beds frequently alternate with thin shales, and occasionally a seam of coal interposes.

The upper and lower coal measures series contain productive seams of coal, while some measures of ironstone are met with in the lower series. The Pennant Grit, however, is the principal division of the coal measures in which ores of iron are met with, and in the neighbourhood of Bristol these ores have been wrought in several localities.

In the millstone grit, at the base of the coal measures, beds or courses of iron ore are occasionally met with; the millstone grit, it may be stated, is familiarly known as the "Farewell Rock," from the fact that when reached there is no longer any probability of meeting any coal in depth. The millstone grit in Somersetshire and Gloucestershire has a varying thickness. In the Mendip Hills it does not exceed 500 feet in thickness, while in the Bristol area it may be taken as varying from 800 to 1,000 feet. It is composed of beds of sandstone, grit, hard and close grained, thin beds of sandy shale, with occasional seams of coal and beds of conglomerate containing quartz pebbles.

The carboniferous or mountain limestone upon which the millstone grit reposes, is also a repository of the ores of iron in this area: it is made up of numerous beds of grey and blue limestone, interstratified here and there with chert in bands and strings. These beds are traversed by joints, veins and faults, in which are found the deposits of ore in irregular veins, pockets, and fissures. The true carboniferous limestone in this area has an average thickness of 3,000 feet and rests upon the lower limestone shales, the lowest member of the carboniferous system, having an average thickness of not less than 500 feet, and forming as it were a passage between the old red sandstone and the carboniferous limestone: it consists of shales and limestones, occasionally sandy and micaceous, varying in colour from blue to grey, and brown, while in the uppermost part are beds of tough bluish limestone.

Three coal basins in isolated tracts occur in the area of the Somerset and Bristol coal-field, namely, that of Bristol and Radstock; of Clapton-in-Gordano; and Nailsea.

The Bristol and Radstock Coal Basin.—The extreme length of this coal-field from its northern apex at Cromhall to the flanks of the Mendips is about twenty-five miles; at Frampton Cotterell it has an average width of four and-a-half miles, from Stapleton to Mangotsfield about five miles, and a line drawn from Bristol

eastward to Naishcombe Hill about six miles. In the above area the coal-field may be conveniently divided into two sections, or into a northern and southern basin, separated by the Kingswood anticlinal, which forms a natural division. Mr. McMurtrie remarks that the whole of the northern part of the coal-field commencing at Kingswood has been raised to a higher elevation than the Somersetshire end of the basin, and it has thus been more exposed to those powerful denuding forces which have swept over the district. In the northern basin the upper coal measures yield but four workable seams of coal. At Coal Pit Heath the succession of beds is illustrated by the following section :—

FROG LANE PIT, COAL PIT HEATH.

(From the Report of the Royal Coal Commission.)

	Ft.	In.
Coal measures	455	2
Rag Coal	0	10
Coal measures	16	0
Top or Hard Coal	2	0
Coal measures	71	6
Stinking Seam	0	6
Coal measures	10	0
Holybush Seam	2	0
Coal measures	68	0
High Seam (in two bands)	4	0

In the southern or Radstock basin the following section shows the succession of strata in the district at the Paulton Engine Pit:—

PAULTON ENGINE PIT.

(From the Report of the Royal Coal Commission.)

	Ft.	In.
Coal measures	348	0
Great Seam	2	0
Coal measures	34	0
Upper Little Seam	1	6
Coal measures	82	6
Middle Seam	1	1
Coal measures	82	11
Slyving Seam	1	10
Coal measures	32	2
Under Little Seam	...	
Coal measures	...	
Bull Seam	0	9

The Clapton-in-Gordano, and Severn Basin.—This coal tract, the exposed portion of which lies between Clevedon and Port-

bury, has in recent years been the subject of much interest occasioned by the discovery of coal measures in the bed of the Severn, east of Almondbury.* The following is the account of a boring made near to Clapton Farm: †—

	Ft.	In.
Soil and New Red Sandstone	10	0
Dolomitic conglomerate	11	0
Pennant Grit	114	0
Bed of marl with water	1	0
Pennant Grit	20	0
Clay	5	2
Coal	0	10
Shales	60	0
Pennant Grit	220	0
Shales	5	0
Pennant Grit	63	0
Total	510	0

Coal also appears to have been found, one seam four feet thick, in the railway cutting at Almondbury, and at Cattybrook, burning freely with a white ash; these seams lying almost vertically appear to have been worked during the past century, from the fact that old tokens (1756) of the Birmingham Mining Company have been found there.

Nailsea Basin.—The upper coal measures are absent in this basin; at Nailsea the Pennant Grit occupies all the central part of the valley about Nailsea church and village, and is seen to pass westwards. Its maximum thickness at Nailsea appears to be about 150 yards, and it contains a good seam of workable coal known as "Grace's Seam," three feet thick, which has been extensively wrought from several shafts in the neighbourhood of Nailsea church.‡ In the upper series of coal measures there are 16 seams of coal, in the Pennant series from two to three, and in the lower series 26 seams in the central area, decreasing to seven in the northern area.

THE RADSTOCK GROUP contains eight seams, varying from 10 inches to two feet four inches, and even more in thickness, giving from 70 to 100 feet thickness of coal. The group in the Farringdon series has eight seams, varying from 1 foot to 3 feet

* "Royal Coal Commission Report," vol. i., p. 57.

† "Coal-fields of Gloucestershire and Somersetshire," p. 55.

‡ "Coal-fields of Gloucestershire and Somersetshire," p. 66.

10 inches in thickness. Again, at Coal Pit Heath, and Parkfield in Gloucestershire, there are six seams, varying in thickness from 18 inches to 2 feet 10 inches.

THE NETTLEBRIDGE DISTRICT contains four seams of coal in the Pennant Grit which have been occasionally worked; the coal wrought from these seams is mostly small, and the hardness of the rock and the presence of water renders the working of these thin seams unprofitable. The lower coal measures contain the most valuable and the greatest number of coal seams, which are also those most extensively worked. In the Nettlebridge Valley this series comprises about 25 seams, varying in thickness from 15 inches to 6 feet. At Bitton Bristol and Kingswood there are about 29 seams, varying in thickness from 1 foot to 6 feet.*

Coal has been wrought, though not in considerable quantities, for three or four centuries, in the Nettlebridge Valley, and probably in the neighbourhood of the Bristol coal-field. In the working of the coal seams, the "long wall" system is that usually adopted, and Mr. W. W. Smyth observes, "that the mode of working adopted in the district, coupled with certain local advantages, has rendered it possible to work coal seams of little more than one foot thick." † At the Writhlington collieries a seam is worked which often does not exceed 8 to 10 inches in thickness. This would not be worked if it were continuously of such small size, but its ordinary thickness is 14 inches in the neighbourhood of Radstock.

Underground water appears rarely to interfere with the working of coal in this coal-field; in reference to this point Professor Prestwich observes that "the faults as usual assist in impeding the circulation of underground water. But probably this is owing to the great extent of secondary rocks covering and protecting the outcropping edges of the coal measures from rain and surface waters." ‡ In some districts, however, as at Kingswood, the water accumulated in the old workings is a source of great danger to modern collieries, so much so, that the fear of tapping them has retarded to some extent mining operations.

* "East Somerset and Bristol Coal-field," pp. 32, 33.
† "Coal and Coal Mining," 1867, p. 64.
‡ "Coal Commission Report," vol. i. p. 41.

Analyses of the Coal.—A few examples of the constituents of the coals raised in the Bristol coal-field will show generally their commercial value. The coals from the Radstock seams are usually considered as the best for household purposes; they burn briskly, make a clear fire, and as they give out a great heat are valuable as a cooking coal, and leave but a small quantity of ash. The Hard Vein or Top Coal, the uppermost seam of the workable coal, having a rock roof of considerable thickness above, the seam largely composed of stems of calamites, &c., in the body of the coal, causing some difficulty in working it free from shales and impurities. Another seam, lower in the series, is the "Holybush," a coal tolerably hard and suitable for gas manufacture. Analyses of these seams give the annexed results:—

Constituents.	Hard Seam.	Holybush Seam.
Ash	4·27	5·93
Fixed Carbon . . .	63·55	59·10
Volatile matter . . Water	32·18	34·97
	100·00	100·00
Specific gravity . .	1·28	1·28
Sulphur	1·625	1·64

One pound of coal of the Hard Seam will convert 13·80 lbs. of water into steam at the temperature of 212° Fahr. The evaporative power of the Holybush Seam being 14·40 lbs. of water converted into steam under the same conditions.

The "Great Vein" of the Kingswood series, and indeed of the Bristol coal-field, is greatly valued as a steam coal, and is extensively used in the Bristol district as a house coal; the seam averages from 4 ft. 6 in. to 5 ft. in thickness, is easily wrought, though requiring much timbering to keep the roads secure and the workings safe; and it is said to be very free from dirt. Other good workable seams, the "Two-foot," or "Little Toad Vein," and the "Lower Fire Coals," may be referred to; this last seam is made up of five coals with shaly partings, the latter collectively 2 ft. thick, leaving 3 ft. of coal. The top of this seam is sound, and the ironstone measures in the roof render it

a valuable seam. The above-named coals show the annexed results on analyses :—*

Constituents.	Great Vein.	Little Toad Vein.	Lower Five Coals.
Ash	5·84	9·59	7·64
Fixed Carbon . . .	70·84	69·80	68·10
Water	1·50	1·43	...
Volatile matter . . .	21·82	19·18	24·26
	100·00	100·00	100·00
Sulphur	1·16	1·80	1·85
Specific gravity . .	...	...	1·34

Production and Distribution of Coal.—In the beginning of the present century there were 24 collieries in Somersetshire, with a total of 29 pits from which coal was drawn; they were distributed as follows in districts :—

Districts.	Collieries.	Pits.
Nettlebridge	7	8
Paulton	10	14
Radstock	7	7
Total .	24	29

At the time referred to (1800) careful inquiries assume that 20 tons of coal were daily drawn from each pit, giving an annual production of 185,540 tons; since, however, many of the collieries would lie idle in summer, and all of them working leisurely, it is estimated that not more than 140,000 tons were raised. The general character of the coals raised will appear from the following remarks by Professor Prestwich :†—"The quality of the coals of the Somersetshire and Gloucestershire coal-field is not such as to compete for household purposes with the Newcastle coals in other markets, owing to their leaving an ash in burning. Many of the seams are otherwise of a good and useful description, whilst others are extremely well adapted for steam and locomotive purposes, for gas making, and some are especially

* "The Bristol Coal-field," a paper read before the British Association, at Bristol, 1875.

† "Coal Commission Report," vol. i., p. 39.

valuable as smiths' coal and for iron smelting. With the exception of their use for the latter purpose, which even now leads them to be sent to Reading and as far as Birmingham, they are not likely, for the present at all events, to be much sought after for a distant supply."

The seams in the upper coal measures at Radstock and Farrington furnish good household coals, those in and around Bristol are chiefly used for gas manufacture. The lower coal measures in Gloucestershire furnish some good household coals, particularly the Kingswood "Great Seam;" they also yield smiths', coking, and steam coals. In the Nettlebridge valley the seams generally afford good smiths' or coking coal.

In the year 1864 Messrs. Greenwell and McMurtrie gave the following as the number of collieries and pits in the Radstock district; they were:—

Districts.	Collieries.	Pits.
Nettlebridge . . .	4	4
Radstock	10	13
Paulton . . .	12	12
Total .	26	29

The estimated daily output in the same year being—Nettlebridge, 290 tons; Paulton, 650 tons; and Radstock, 1,160 tons, giving a daily total yield of 2,100 tons. Making due allowance for inactivity during the summer months, the annual production of coal did not exceed 600,000 tons. In the year 1867 the output of these collieries amounted to 413,678 tons; the details are thus given:—

Districts.	Coal.	Slack.	Total.
	Tons.	Tons.	Tons.
Nettlebridge . . .	10,919	8,081	19,000
Radstock	219,502	38,940	258,442
Paulton . . .	110,846	25,390	136,236
Total .	341,267	72,411	413,678

In order to arrive at the total returns of coal raised in Somersetshire it is necessary to add an additional return of six collieries

in the Radstock district, not included in the above, also coal allowance to workmen, and engine coal. The output of the Radstock collieries would therefore stand as follows for the year 1867:—*

	TONS.
Returns received	413,678
Radstock (additional)	115,000
Workmen's coal	7,000
Engine coal	10,000
Total	545,678

For a few years the collieries in the Radstock and Nailsea districts are separately distinguished, producing coals in the following quantities:—

Year.	Radstock.	Nailsea.
	Tons.	Tons.
1863	...	22,295
1864	600,000	33,234
1867	545,678	23,224
1868	586,000	20,000
1869	539,000	...

The production of the Nailsea collieries in 1868 was distributed as follows:—†

DISTRIBUTION AND USES.

	TONS.
The glass works consumed	15,500
Sales in the country around	3,000
Engine coals and pit fires	1,250
Colliers' allowance	250
Total	20,000

Since the year 1870 the output of the collieries in the Somerset coal-field, together with the produce of collieries in the Bristol district, are available, and are given in the following quantities, with the total number of collieries in both divisions of the coal-field; the production of Somersetshire, in 1880, amounting to 757,802 tons, and the Bristol Coal-field 475,807 tons, giving a total of 1,233,609 tons, compared with 1,048,567 tons in the year 1870:—

* "Coal Commission Report," vol. iii., p. 127. † Ibid., 126.

Year.	Somersetshire.		Bristol.		Total.	
	Collieries.	Coal.	Collieries.	Coal.	Collieries.	Coal.
	Nos.	Tons.	Nos.	Tons.	Nos.	Tons.
1870	34	525,000	18	523,567	52	1,048,567
1871	35	673,878	18	573,704	53	1,247,582
1872	33	*	15	*	48	1,280,000†
1873	34	*	16	*	50	1,068,366
1874	38	609,684	18	480,275	56	1,089,959
1875	40	654,878	20	571,000	60	1,225,878
1876	45	650,415	21	589,538	66	1,239,953
1877	41	666,500	20	556,407	61	1,222,907
1878	39	693,000	21	539,121	60	1,232,121
1879	39	767,930	22	471,290	61	1,239,220
1880	39	757,802	22	475,807	61	1,233,609

The returns for the year 1880 giving an increase of 185,042 tons beyond those of 1870, and showing that while the Somerset area of the coal-field has increased its production to the extent of 232,802 tons in the period, the collieries of the Bristol district have fallen off to the extent of 47,760 tons. The distribution of the Somersetshire coal-field is mainly effected by the Great Western Railway, which system carried from the Radstock district coals in the following quantities since 1866:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1865	211,936	1873	237,372
1866	211,948	1874	204,890
1867	222,948	1875	199,456
1868	254,134	1876	183,691
1869	271,326	1877	195,492
1870	294,310	1878	202,031
1871	306,732	1879	203,988
1872	261,657	1880	258,482

The great bulk of the above quantities were carried over the main line of the Great Western Railway, quantities not exceeding one-tenth of the above being passed over the stations beyond their system. The Westbury Iron Company in Wiltshire, it may be observed, derive their supplies of coal for their blast furnaces from their own collieries in the Nettlebridge Valley.

Prices of Coal at the Pit's mouth.—During the years 1868 and 1869, the best varieties of house coal obtained from the Easton and Whitehall Collieries in the Bristol district, varied at

* Production included in South Wales district.

† Production estimated.

the pit's mouth from 10*s*. to 13*s*. per ton; and coal suitable for steam purposes from 5*s*. to 6*s*. per ton, the cost of cartage to Bristol being 2*s*. and to Clifton 3*s*. per ton.

The coal of the Ashton Vale and Bedminster Collieries in the Paulton district were quoted at the same period: Bedminster screened, 10*s*. 6*d*.; picked lumps, 13*s*.; Ashton Vale slack, 5*s*. per ton. In the Radstock district in 1870 the best varieties of coal were quoted as follows:—Bull Hall coal, 11*s*. 8*d*. to 14*s*. 2*d*.; slack, 4*s*. 9*d*. to 5*s*. 6*d*.; Coal Pit Heath, from 7*s*. to 10*s*., and slack, 4*s*. per ton; while in the Paulton and Bedminster Collieries coals varied from 8*s*. to 11*s*., and slack from 3*s*. to 7*s*. per ton.

In the year 1880 in the Bristol district the average prices of best house coals at the pit's mouth was 9*s*. 9*d*., and in Somersetshire generally about 10*s*., the highest price obtained for coals being 14*s*., and the lowest 6*s*. 10*d*. per ton; slack varied from 2*s*. 4*d*. to 5*s*., the average being 4*s*. per ton.

Population employed in Coal Mining.—In the year 1854 the number of persons of all ages engaged in coal mining was 5,180, and in iron mining 68. There is no information available in subsequent years showing the numbers of persons employed until the year 1873, arising from the fact, that in intervening years the numbers thus engaged were included in other districts. In 1873 and since ample information is available, giving the number of persons employed underground and above ground, distinguishing the Somersetshire from the Bristol area of the coal-field.* The numbers engaged in Somersetshire were as follows, with the quantity of coal raised, to which is added the average produce per person in each year:—

SOMERSETSHIRE AREA OF THE COAL-FIELD.

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	3,707	967	4,674	609,039	130
1875	3,674	916	4,590	640,508	139
1876	3,631	891	4,522	650,714	144
1877	3,347	783	4,130	670,256	164
1878	3,348	844	4,192	692,942	163
1879	3,464	786	4,250	742,060	174
1880	3,508	757	4,265	757,802	178

* H.M. Inspectors of Mines' Reports, 1874 to 1880.

The efficiency of the mines in this division of the coal-field shows favourably in 1880 compared with 1874, to the extent of 48 tons per man, equivalent to an increase of 33 per cent.

In the Bristol division of the coal-field the numbers of persons employed were as under, with the coal produced, and the average yield per man :—

BRISTOL AREA OF THE COAL-FIELD.

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	2,713	600	3,313	497,042	150
1875	2,782	675	3,457	571,050	165
1876	2,518	607	3,125	541,853	173
1877	2,516	618	3,134	518,995	166
1878	2,305	590	2,895	482,129	166
1879	2,362	606	2,968	501,559	169
1880	2,382	578	2,960	475,807	160

In that part of the Bristol coal-field in Somersetshire a steady increase per man appears in 1880 compared with 1874. However, to arrive at average results for the whole coal-field, it is necessary that both districts should be summarised; the result is as follows :—

SOMERSET AND BRISTOL COAL-FIELD.

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1874	6,420	1,567	7,987	1,206,081	151
1875	6,456	1,591	8,047	1,211,558	150
1876	6,149	1,498	7,647	1,192,567	156
1877	5,863	1,401	7,264	1,189,251	163
1878	5,653	1,434	7,087	1,175,071	163
1879	5,826	1,392	7,218	1,243,619	172
1880	5,890	1,335	7,225	1,233,609	171

Resources and probable Duration of the Coal-field.—This coal-field has an area of 238 square miles, 14 of which are exposed, including that part in Gloucestershire. The coal-field is remarkable from the circumstance of so large a portion of it

being covered by the New Red Sandstone, Lias, and Oolites, under which it is worked to a considerable extent. Its area may be divided into three portions.*

EXTENT OF THE SOMERSETSHIRE AND BRISTOL COAL-FIELD.

	AREA IN ACRES.
Portion of exposed coal measures	30,580
Portion of coal measures covered by and worked under the newer formations	24,111
Portion of coal measures covered by the newer formations and not yet worked	98,089
Total extent of the Coal Measures . .	152,780

The coal already wrought is estimated to cover an area of 24,111 acres, each acre being estimated to yield 1,500 tons of one foot thick, an allowance of from one-tenth to one-third being made for waste in working, faults, &c. The quantity of coal already wrought amounts to 114,024,685 tons, obtained as follows:—

COAL MEASURES.	TONS.
From the Upper Series	49,698,786
,, Pennant Grit	1,245,025
,, Lower Series	58,080,874
,, sundry small pits	5,000,000
	114,024,685

All this coal, except 27,000 tons, has been wrought at a depth not exceeding 1,500 feet, the 27,000 tons being wrought at a depth of from 1,500 feet to 1,940 feet.

The total coal remaining unwrought and available for use to a depth of 9,000 feet is estimated to amount to 6,944,310,982 tons, from which a deduction of one-fifth is made for possible over estimates on the coals of the lower series (amounting to 4,200,000,000), equal to 840,000,000 tons, leaving the total of workable coal remaining unwrought as above stated 6,944,310,982 tons. Or, taking the total at all depths down to 4,000 feet, there yet remains available for future supplies 4,218,970,762 tons. The distribution of the coal is as follows to the depth of 9,000 feet:—

* "Coal Commission Report," vol. i., p. 36.

		TONS.
1.	Not exceeding 1,500 ft.	1,718,791,280
2.	Between 1,500 ft. and 3,000 ft.	1,519,997,981
3.	,, 3,000 ft. and 6,000 ft.	2,227,531,577
4.	,, 6,000 and 9,000 ft.	637,990,144
	Total to 9,000 ft.	6,104,310,982
	Total to 4,000 ft.	4,218,970,762

Professor Prestwich observes with regard to the duration of the coal-field: The present quantity of coal wrought in this coal-field has been calculated to vary from 750,000 tons (1859) to 1,000,000 tons, at which latter Mr. Cossham estimated it in 1863. Adopting the latter estimate, the quantity of coal remaining unwrought, at this rate of consumption, is sufficient, supposing the whole quantity to be available, for 6,104 years, or supposing a limit in depth, the duration of the supplies from the respective zones would be as under:—

			YEARS.
1.	Not exceeding 1,500 ft.	sufficient for	1,719
2.	Between 1,500 and 2,000 ft.	sufficient for	1,520
3.	,, 3,000 and 6,000 ft.	,,	2,227
4.	,, 6,000 and 9,000 ft.	,,	638
			6,104

Or the total to the depth of 4,000 feet may be estimated as equal to a supply for 4,219 years.*

Taking the production of Somersetshire as recorded in the "Mineral Statistics, 1870," amounting to 1,048,567 tons, and dealing with the above available quantities, sufficient supplies would be ensured by the store of coal to the depth of 9,000 feet for 5,821 years, and to the depth of 4,000 feet for 4,024 years.

Again, deducting the production of the past ten years (amounting to 11,894,553 tons), from the original quantities unwrought, there remained at the end of 1879 to the depth of 9,000 feet 6,092,416,429 tons, and to the depth of 4,000 feet 4,207,076,209 tons, which at the average production of the ten years (1,189,455 tons) would afford supplies at the former depth for 5,122 years, and the latter 3,527 years.

* "Coal Commission Report," vol. i., pp. 50, 51.

CHAPTER XVII.

DEVONSHIRE COAL AND LIGNITE DEPOSITS.

Description of Bovey Tracey Coal or Lignite Deposits—Anthracite of Bideford—Analyses and Production of Lignite and Anthracite.

Devonshire. Bovey Coal, or Bovey Tracey Lignite.—This deposit is found near the town or village of Bovey Tracey, on the left bank of the river Bovey, and about two miles and a half above the point at which it falls into the river Teign, being about eleven miles distant from each of the towns Exeter, Torquay, and Totnes.

The deposit is described by Mr. Pengelly, F.G.S.,* as stretching away in a south-easterly direction, having a length of six miles from a point about a mile west of Bovey to another nearly as far east as Newton; its greatest breadth, from Chudleigh Bridge on the north-east, to Blackpool on the south-west, being about four miles. It forms a lake-like expansion of the valleys of the Teign and Bovey rivers, especially the latter, whose course it may be said to follow in the higher part, where it is most fully developed; whilst the Teign constitutes its axis below the junction of the two streams. Its upper or north-western portion immediately adjacent to the village, is known as "Bovey Heathfield," and extends over an area of about 700 acres.

Shafts and other excavations have shown that this basin consists of an accumulation of coarse gravel (mixed with sand and clay) of variable thickness, unconformably covering distinct strata of lignite, clay, and sand, which are familiar to geologists as the "Bovey deposit," whilst the lignite is equally well known as "Bovey Coal." This deposit not only occupies the plain which has been described, but is continued in a narrow southerly direction from Newton, to near Kingskerswill, about three and a half

* "Memoirs on the Lignites and Clays of Bovey Tracey." Transactions of the Royal Society, part 2, 1862.

miles from Torbay; and where it crosses the estuary of the Teign it is distant about four miles from the coast.

The most important of the excavations is that known as the "Coal Pit," which is situated on the Heathfield, somewhat less than a mile south of the village, and about the same distance from the western margin of the deposit. It is open to the day, and is in form a rude parallelogram, having its longest side about 960 feet, whilst the shortest measures 340 feet, its greatest depth at the western end being about 100 feet. Subterranean excavations have been carried on very extensively in various directions by means of tunnels opening out of the pit at its bottom.

Attention was first directed to this deposit in the year 1760, when the Rev. Jeremiah Milles communicated his views to the Royal Society in a letter addressed to the Earl of Macclesfield,* although it appears that the lignite was discovered about the year 1745, and probably at an earlier period. Dr. Maton, about the year 1796, in his "Observations on the Western Counties of England," gives some particulars respecting the Bovey deposits, apparently from actual observations. The pits at this time were of considerable depth, 80 feet, and the lignite was worked to supply fuel for a pottery close by. About the year 1812, another pottery was established near Bovey Tracey, called Folley Pottery, from the coal-pits, the lignite being locally known as Folley Coal. In 1853 the pottery kilns were fired with lignite; later, in 1869, it was not employed in the earthenware kilns, the small quantity then used being in the brick-works of the neighbourhood, where it is also used in small quantities in the cottages, but the disagreeable smell which it gives out in burning renders it objectionable.

Some years since a company engaged in working iron ore at Ilsington proposed to use this Bovey lignite for smelting the ore; two blast furnaces were commenced, but ere they were completed the company was dissolved, and the experiment for using this lignite for iron smelting was never tried.

Analysis of the Bovey Tracey Lignite.—The Bovey coal, examined by Fred. Vaux, Esq., in his paper "On the Ultimate Analysis of some Varieties of Coal," † is thus described:—Be-

* "Philosophical Transactions," li., part 2, p. 534, &c.

† "Journal of the Chemical Society of London," vol. i., p. 318 (1849).

comes quite rotten after immersion in water; that it does not soil the fingers; that the coke has a semi-metallic lustre, does not smell, cakes but slightly, and does not take the form of the crucible; that it is easily converted into a bulky red ash, interspersed with filaments; that before the blowpipe it is partially, but with difficulty, fusible into a black clinker; and that its composition is shown in the annexed table, giving the relative proportions in 100 parts of Bovey lignite, exclusive of water.

RESULTS TABULATED.

Carbon	66·314
Hydrogen	5·627
Oxygen	22·861
Nitrogen	0·565
Sulphur	2·364
Ash	2·269
Water	34·660
Coke	30·799

Free from Water and Ash.

Carbon	67·8535
Hydrogen	5·7576
Oxygen	23·3920
Nitrogen	0·5781
Sulphur	2·4188

Copper and lead, it is stated, were detected in the ash.

Another sample of the Bovey lignite called "Board Coal," from a bed about four feet thick in the "Board Coal Seam," is thus described in Dr. Percy's "Metallurgy."* The analysis was made by Mr. William Ratcliffe, and was communicated by the late Mr. Ebenezer Rogers, of Abercarne, near Newport, Monmouthshire:—"It abounds in the remains of dicotyledonous plants, and is woody in structure. It is said to yield a bright, hard, porous coke. The hygroscopic water was estimated by the loss in weight by drying at 100° C., and the specimen analysed had been previously dried at that temperature. It is stated that there are also twenty seams of what is locally termed "rough coal," with which a large proportion of clay is intimately mixed; a specimen of this variety yielded after air-drying at 37° C., 52·37 per cent. of coke, containing 29·98 of ash, which contained 0·532 per cent. of phosphoric acid, and of which 65·48 per cent.

* "Fuel," 1875, pp. 312, 313.

was insoluble in hydrochloric acid, and consisted chiefly of silica."

The results appear in the annexed analysis, the composition per cent. being exclusive of water, which gave 2·21 per cent., the yield of coke amounting to 51·50 per cent.

RESULTS TABULATED.

Carbon	66·76
Hydrogen	5·59
Oxygen	22·81
Sulphur	2·09
Ash	2·75
	100·00

The composition per cent., exclusive of ash and water, being carbon, 70·15; hydrogen, 5·88; oxygen and nitrogen, 23·97 per cent.

Production of Lignite.—The quantity raised at the Brown Coal Mine in the year 1854 amounted to 15,000 tons; in subsequent years the output has been as follows:—

YEAR.	TONS.
1856	5,600
1857	3,850
1867	1,368
1868	1,383

The above are the only returns obtainable. Since the last-named year some quantities have been raised from time to time, but being included in other districts the exact quantities are not known.

Bideford Anthracite.—Another description of coal which has been worked in Devonshire is the variety known as culm or anthracite of Bideford. These beds of anthracite stretch across the country, from Barnstaple Bay by Bideford and Alverdiscot towards Chittlehampton, and there are evidences that these culm deposits were worked on the line of the out-crop at a remote period. Many old workings have from time to time been discovered, some of the pits having been carried to depths of from eight to ten fathoms. The beds of culm are very variable in thickness, the middle or great anthracite bed upon which all the chief workings have been carried is described as varying from

6 inches to 14 feet in thickness, the average being about 7 feet. According to Lysons, the beds in the vicinity of Eastacot were extensively worked in the middle of the last century. A pit here was re-opened about the year 1790, and abandoned in the following year on account of the water, when the pit reached a depth of 25 fathoms, the quantity of anthracite raised being about 900 bushels per week.

Sir Henry de la Beche,* writing in 1838, says, culm or anthracite beds are now at work about a mile on the east of Bideford. Mr. John Rundle, M.P., who is interested in them, states that about twelve or eighteen months previously, they drove a little under the adit, and in a short time obtained from 600 to 700 tons of anthracite. It appears that these mines were partially opened about 1825 for 200 fathoms in length, above an adit 15 fathoms deep. The eastern mine in full work employed three men and five boys, and produced about 700 bushels or 58 tons of anthracite per week. From the western mine about 1,500 tons were raised in the year. The quantities raised of late, as far as returns are available, are inconsiderable, and are as under:—

YEAR.	TONS.
1854	6,500
1856	5,036
1857	4,173

Some quantities, it is said, were raised in the year 1877 and since; they were, however, small, and do not appear to have been recorded.

This fuel was at one time extensively used at Greenacliff in Barnstaple to burn with the limestones brought there from South Wales. A variety of the anthracite, probably formed from decomposed portions of it, has long been raised near Bideford and employed as a pigment. Lysons † says it was used in Plymouth in 1822, and at a later period it was sent to Chatham for the same purpose. The quantity (paint-clay) raised in the year 1880 amounted to 200 tons.

* "Geological Report on Cornwall, Devon, and West Somerset," 1839, p. 514.

† "Magna Britannia," Devonshire, p. ccxcii.

CHAPTER XVIII.

THE COAL-FIELDS OF SCOTLAND.

General Description of the Coal-fields—The Carboniferous Series of Scotland—Section of Strata, Order and Occurrence of Coal Seams and Ironstone Measures in different Areas—Varieties of Coal and Analyses—Gas Producing Coals, Cannels, Analyses, and Yield of Gas in Cubic Feet—Production of Coal in the Eastern and Western Districts, and of the several Coal-fields—Distribution Coastwise and to Foreign Countries—Railway Distribution—Prices of Coal and Cost of Production—Population Employed in Coal and Ironstone Mining—Resources and probable Duration of the Scotch Coal-fields.

Coal-fields of Scotland.—The carboniferous rocks of Scotland cross the country in a direction from south-west to north-east, stretching from sea to sea, from the Firth of Clyde on the east to the Firth of Forth on the west, and occupying the great synclinal hollow or trough along the valley, and parallel to the mountain chains of the Grampians and Lammermuirs, or between the slopes of the Grampians and the north flanks of the southern uplands. This great hollow, or depression, is filled with a coal-field nearly 100 miles in length, extending from Saint Andrew's, near Greenock, to the eastern coast, and from Dalkeith, near Edinburgh, to Ayr on the western coast, an average breadth of 25 miles. The area thus described is not all productive of coal; in it occur several distinct coal-fields, or basins, divisible into six, viz., the coal-fields of the Clyde basin, the Mid Lothian, Edinburgh and Haddington coal-field, the East Lothian coal-field, the Fifeshire, Clackmannan, Ayrshire, and Lesmahago coal-fields.

The greatest part of the workable coal seams of the Scottish area is included in the carboniferous limestone group; for the English lower carboniferous rocks undergo a gradual physical change in their extension, from south to north, or from the Midland Counties into Northumberland and South Berwickshire, and coal seams occur and are worked in them near the base, associated with thick beds of shale, the calcareous beds having greatly diminished. Below the equivalents of our carboniferous limestone are a series of white and grey sandstones, shales,

cement stones, and thin coal seams. These equal the English lower limestone shales, and are termed "calciferous sandstones," which sometimes attain a thickness of 4,000 feet.

The carboniferous series of Scotland, divisible into four groups, are thus classified by Professor A. Geikie, F.R.S., in the third edition of Juke's "Manual of Geology:"—

DIVISIONS.		ENGLISH EQUIVALENTS.
4. Coal measures	Red sandstones (Hamilton) white and grey sandstones, shales, fire-clays, coal seams, and ironstone.	Middle and Lower coal measures.
3. Millstone grit	Moorstone rock, or Roslin sandstone and conglomerate.	Millstone grit and Yoredale series.
2. Carboniferous limestone series.	Sandstones, sometimes coarse shales, coals, black-band, and clay-band ironstones, oil shales, and fossiliferous limestones.	Carboniferous or mountain limestone.
1. Calciferous sandstone series.	White and grey sandstone shales, cement stones, cyprid limestones and occasional coal seams.	Lower limestone shale.

The aggregate thickness of the carboniferous series of the centre of Scotland gives a section of from 8,000 feet to 9,000 feet, the greater part of which is regarded as of marine origin.

The lowest series, the calciferous sandstones, may be described as being composed of a lower group of red sandstones and another group, the characteristic feature of which is the presence of bituminous shale. Next in order of occurrence ascending appears the carboniferous limestone series, divisible into three well-marked groups. First, an upper group, consisting chiefly of sandstone, &c., and with some three or more seams of limestone; the second, a middle group of sandstones and argillaceous shales, with numerous seams of coal and ironstone, but no limestone; and the third, a lower series or group of strata, with seams of coal and ironstone and a variable number of limestones.

The lower group is very variable as regards the number and quality of its coal, ironstone, and limestone seams, and the absolute thickness in which these occur. In some districts, as in Ayrshire, one or two limestones occur in a thickness of eight or ten fathoms of strata, and not unfrequently no coal or ironstone

seams of commercial value. In other localities, as at Carluke, and along the southern borders of the Lanarkshire coal-field, no fewer than eleven limestones occur in a thickness of 35 fathoms of strata, while at the same time occur a number of excellent bands of argillaceous ironstone. The middle group of the limestone series is characterised by the presence of numerous coal and ironstone seams, and by the total absence of limestones. One or two seams of black-band ironstone appear in this horizon, and about midway, between the top and bottom of the series, occurs the celebrated Lesmahago gas-producing coal, yielding 13,500 cubic feet of gas, of a high illuminating power, from one ton of coal. The upper limestone group, of the carboniferous series, as exhibited in Lanarkshire, has a great sameness of character in all the localities where it occurs. Usually it contains three limestones, and here and there one or two lenticular and inconstant seams of the same mineral, of variable qualities and thickness. Mr. James Geikie, in his interesting papers on the "Coal and Ironstone-bearing Strata of Scotland," from which many of the foregoing facts are drawn, considers that the numerous coal seams point to the frequent occurrence of a land surface, and the gas coals and ironstones to the former existence of numerous wide lakes and lagoons.

It is not uncommon to find lines and ribs of gas coal associated with seams of splint, and even with seams of common coals. Gas coals are not unfrequently found to pass into common coals, or into black shales, and sometimes into black band ironstone, and thus the same mineral seam may be alternately a common splint or gas coal, an oil shale or a black-band ironstone, according as the physical condition varied at the time of its formation. The millstone grit, reposing on the carboniferous limestone series above referred to, occasionally yields clay ironstone of good quality, the Curdly seam being the best known, and is an ironstone of variable thickness and purity, occurring in nodular masses. The coal measures at the top of the series, reposing on the millstone grit, consist of two groups, the upper consisting of a series of red sandstones, with intervening sandy marl and impure fire clays, resting unconformably upon the coal-bearing strata, and in the deeper parts of the Lanarkshire coal-field attaining a thickness of upwards of 700 feet. The lower or coal-bearing group, rich in coal, containing 18 workable seams; it

also contains several important seams of black-band and clay-band ironstones, which have been extensively wrought, and some nearly exhausted. The black-bands vary considerably, and do not often exceed 18 inches in thickness. In one locality, however, the Crofthead slaty-band is said to have reached the thickness of six or seven feet.

In the Western coal-fields of Scotland seven principal black-band measures are known, occurring in the following order :—

	Thickness. Ft.	In.
Palace Craig, *black-band*	1	2
Airdrie, *black-band.*	1	4
Bellside, *black-band*	0	6
Kiltongue, *black-band*	0	8
Calderbank or Kennelburn, *black-band*	0	6
Upper slaty, *black-band*	1	3
Lower slaty, *black-band*	0	8

The above thicknesses are, however, subject to considerable variation, and the same seam is rarely continuous over any large area. Thus, at Airdrie, it occurs in workable quantities over an area not exceeding ten square miles, but its equivalent, in the form of a thin seam of coal, extends over an area of between 50 and 60 square miles. In Linlithgowshire the equivalent of the black-band ironstone is found in the celebrated Boghead cannel coal, or as it is also known by the name of the Torbane Hill mineral, which some years ago gave rise to much litigation.

The foregoing brief sketch of the carboniferous series of Scotland shows generally the geological features bearing on the occurrence of the coal seams and ironstone measures; some of the more important of the latter, as they occur in the Western coal-fields, being noted above. The next subject to follow will be the several coal-fields of Scotland.

Clyde Basin Coal-field.—This important coal-field, the largest in Great Britain, is traversed throughout its entire length by the Clyde, and includes the greatest part of the Shires of Renfrew, Dumbarton, Stirling, and nearly the whole of Lanark. The coal-bearing series are 4,000 feet thick, divided into upper, middle, and lower, and respectively 840 feet, 960 feet, and 2,200 feet thick, the base of the whole being the calciferous sandstone. The upper and lower series are the chief repositories of the coal seams. The upper series has ten seams of coal exceeding two feet in thickness, and three valuable bands of ironstone. The

lower series contain three courses of ironstone, and several valuable beds of coal, west of Glasgow. The black-band ironstones occasionally pass into coal seams, the carbonaceous matter gradually replacing the argillaceous carbonate of iron.

The following section, communicated to the Philosophical Society of Glasgow by Mr. William Moore, shows the order of occurrence of the coal and ironstone series in that part of the coal-field lying in the valley of the Clyde:—

COAL AND IRONSTONE SERIES.

DEPTH IN FATHOMS.			THICKNESS. Ft.	In.
42.	Palace Craig *Ironstone* (impure)		0	0
48.	Upper Coal (good)	3 ft. to	4	6
63.	Ell Coal (good)	4 ft. to	8	0
67.	Pyotshaw Coal (splint) average		4	0
68.	Main Coal (good soft quality)	3½ ft. to	5	0
76.	Humph Coal		1	8
81.	Splint Coal (for iron smelting)		3	0
84.	Sour Milk Coal (variable)		3	0
103.	Mushet *Black-band Ironstone*		1	4
106.	Soft-band *Ironstone*		1	8
120.	Curly-band *Ironstone*		0	5
127.	Virtue Well Coal		2	6
132.	Bellside *Ironstone*		0	7
134.	Calderbrae *Ironstone*		0	8
136.	Kiltongue Coal (variable)		5	0
148.	Drumgray or Coxrod Coal		2	0
203.	Slaty Black-band *Ironstone*		4	6
208.	Boghead Gas Coal (1 to 20 in.)		0	10
447.	Possil *Ironstone*		1	0
467.	Lesmahago Gas Coal		1	0
502.	Govan Band *Ironstone*		1	0

Analyses of the Coal.—The brown Cannel coal known as the Torbane Hill Mineral, and previously referred to, occurs in the upper coal measures, immediately above the millstone grit, having a thickness varying from 16 inches to 2 feet, in contact with shale and clay ironstone, and resting on a bed of underclay, after the manner of ordinary coal. The principal localities in which it occurs is at Torbane, Inchcross, Boghead, Cappers, and Bathvale near Bathgate. It is the most valuable mineral known for making gas and paraffin oil. Dr. Andrew Fyfe, who examined and determined its composition, obtained from a single ton 14,880 cubic feet of gas, of an illuminating power equal to 7·72 spermaceti candles, besides 700 lbs. weight of coke; it also yields, on distillation, 125 gallons of paraffin oil per ton. A

striking characteristic of this Cannel is its indestructibility under atmospheric exposure, which does not depreciate its value in its gas-giving powers. Out of Scotland the only other localities in which Cannel coal is worked is at Leeswood (south of Mold), in Flintshire; Wigan, in Lancashire; and at Newcastle. The following table shows the results of Dr. Fyfe's examination of the Torbane Hill Mineral in comparison with other well-known Cannel coals. In Scotland the term "Parrot Coal" is applied to Cannel coal, from the loud crackling noise with which it flies to pieces, when placed upon the fire:—

	LEESWOOD.		Lancashire Wigan Cannel.	Torbane or Boghead Cannel.
	Smooth Cannel.	Curly Cannel.		
Cubic feet of gas per ton	9·972	14·280	12·100	14·880
Durability of gas per foot	55·05	82·30	48·35	84·400
Illuminating power per foot, candles	8·2	1·09	5·00	10·300
Grains of sperm per foot	0·981	1·308	0·36	1·242
Value of coals in pounds of sperm	1401·7	2668·3	617·00	2736·000
Comparative value of the coals	5·610	5·025	...	2·86

Other analyses of coal, made by Mr. Lewis Thompson, exhibit the following constituents; of these the Lesmahago Cannel is thus described: "massive, dull black; principal fracture, slaty conchoidal; cross fracture, conchoidal and angular; streak, black and somewhat shining: thrown on the fire, decrepitates slightly; does not split or fuse; colour of ash, white, with nitrate of cobalt, dirty blue; specific gravity, 1·220":—

Constituents.	Lesmahago.	Boghead.	Capeldrea.	Lochgelly.
Volatile matter	49·60	68·40	54·50	33·50
Coke	50·40	31·60	45·50	66·50
Ash	9·10	22·80	10·50	13·10
Sulphur in coal	2·23	0·53	0·65	0·75
Sulphur in coke	1·14	0·08	0·20	0·25
Sulphur in volatile matter	1·09	0·45	0·45	0·50
Ash in coke per cent.	18·05	70·25	23·07	29·70

The average yield of gas in cubic feet per ton of the above coals appears as follows: Lesmahago, 13,500; Capeldrea, 14,000;

and Lochgelly, 9,500. The above results were obtained after three distinct experiments were made upon each variety of Cannel operated upon. Another variety of Cannel, the Pirnie, at Methill, gives on analysis the following results:—

RESULTS.

Specific gravity	1·126
Gas, per ton	13·500 cubic feet
Illuminating power	28 candles
Coke and ash	36·00 per cent.
Hydrocarbons	20·00 ,,
Sulphuretted hydrogen	·50 ,,
Carbonic acid	4·75 ,,
Carbonic oxide	7·75 ,,
Volatile matter in coal	65·00 ,,
Specific gravity of gas	·700

In the annexed statement appears the respective yield per ton in cubic feet of Cannel coals, extensively used in the manufacture of gas in Great Britain:—

Cannels.	Counties.	Cubic Feet per Ton.
Boghead or Torbane Mineral	Linlithgow	14,880
Lesmahago	Lanark	13,500
Methill Pirnie	Fife	13,500
Overtown	Lanark	13,000
Wemyss	Fife	14,300
Arniston	Midlothian	12,600
Ramsay	,,	10,300
Kirkness	Kinross	12,800
Capeldrea	Fife	14,000
Skatrig	Lanark	10,400
Lochgelly	Fife	9,500
Rigside	Lanark	10,400
Rochsoles	,,	11,900
Leeswood (smooth)	Flint	9,972
,, (curly)	,,	14,280
Wigan	Lancashire	12,100
Ince Hall	,,	11,673
Pelton	Durham	11,500
Leverson	,,	11,600
Washington	,,	10,500

The quantity of coal used in Scotland in gas manufacture, as determined by the Royal Coal Commission in the year 1867, amounted to 263,261 tons, and in the year 1868 to 299,919 tons.

The celebrated Lesmahago gas coal, yielding 13,500 cubic feet

of gas, of a high illuminating power, exhibits the following constituents on analysis by T. H. Read, Esq. :—

RESULTS TABULATED.

Carbon	36·70
Volatile material	56·23
Sulphur	·55
Ash	4·30
Water	3·15
Total	100·93

The coals used in iron smelting and manufacturing purposes in Scotland, are numerous and various. In iron smelting, the Splint coal is generally employed in the furnace without previous coking, and from the following selected analyses it will be seen that these coals do not vary to any considerable extent in composition. The Splint coal is a variety of bituminous (Cannel) coal, with a slaty structure ; its constituents appear in the annexed analyses :—

Constituents.	1.	2.	3.	4.
Carbon in coke	52·83	54·25	52·04	53·77
Volatile products	35·57	32·95	39·14	31·07
Sulphur	·36	·20	·11	·34
Ash	2·38	3·25	1.07	4·27
Water	8·86	9·35	7·6	10·55
Total	100·00	100·00	100·00	100·00
Coke per cent.	55·35	57·58	54·05	58·45
Specific gravity	1·31	1·293	1·255	1·240

Coal for domestic purposes is extensively furnished by the following coal seams: the Ell, Main, Pyotshaw, Virtue Well, Kiltongue, and Drumgray. The last-named give the constituents following, on analyses :—

RESULTS TABULATED.

Carbon	55·8
Hydrogen and Oxygen	5·4
Sulphur	2·0
Nitrogen	34·0
Ash	2·8
	100·0

The coals of the above-named seams are also employed for steam purposes. As it might be interesting to view the quantity of coal in the light of the power it is capable of giving out, Mr. Ralph Moore, H.M. Inspector of Mines, illustrates the point. He states that a steam engine of average quality consumed ten pounds of coal per horse-power per hour, or it consumed 100 lbs. every day of ten hours while it did the work of a horse. A ton of coal would supply a horse's power for 24 days, and the quantity of coal raised in Great Britain, say 125,000,000 tons, would supply the power of 10,000,000 horses, or five times as many men. The coal annually exported, say 15,000,000 tons, would supply the power of 6,000,000 men. Taking the consumption of coal at 12 tons for the power of five men, and the coals at 10*s.* per ton, the power of five men could be obtained for £6 per year, or a man's power could be obtained for 25*s.* per year, 6*d.* per week, or 1*d.* per day, and thus the coal raised in the United Kingdom would be equal to an army of 50,000,000 of men, giving out their work at one penny per day.*

The Mid-Lothian, Haddington, and Edinburgh Coal-field.—This triple coal-field on the south-western side of the Firth of Forth, the waters of which separate it from the Fifeshire coal-field, possesses much interest geographically and physically, and with the Fifeshire area are the most interesting of the Scotch coal-fields. This triple coal-field, described by Professor Hull as a double trough, the deeper of which lies in Edinburghshire on the west, and the shallower on the east in Haddingtonshire, has nearly 50 seams of coal of varying thickness, giving in the aggregate 122 feet of solid coal. Celebrated amongst other coals here occur the 8-feet "Great Seam," and the "North Greens," 1,500 feet below the "Great Seam," yielding the well-known Parrot coal, having a thickness of 3 feet, and greatly esteemed as a coal for the manufacture of gas. Both the above-named seams occur in the carboniferous limestone, which has, in a section of 1,600 feet, 17 workable seams of coal; the coal measures proper, reposing on the millstone grit, having a thickness of 1,220 feet, in which are found 11 seams of coal. This coal-field has an area of 64 square miles, and the following section, taken from the centre of the coal-field near Dalkeith, shows the various coal-seams and their order of occurrence.

* Lecture by Mr. Moore. See Report, "Mining Journal," 4th March, 1876, p. 259.

COAL SEAMS OF MID LOTHIAN.

	Ft.	In.
Sandstone and shale	346	0
Clay Knowes Coal	3	6
Splint Coal	3	10
Beefie Coal	3	6
Jewell Coal	4	0
Coal	2	8
Cowpit's Little Splint	2	2
Cowpit's Five-foot	5	6
Glass Coal	2	0
Burr's Coal	4	0
Cowpit's Three-foot	3	0
Cowpit's Six-foot	4	6
Millstone Grit	340	0

In this same area the carboniferous limestone series has a thickness of 1,590 feet, in which appear numerous seams of coal upwards of 2 feet thick, and in the same section are recognised nine seams of ironstone, of 2 inches thick and upwards :—*

CARBONIFEROUS LIMESTONE COAL SEAMS.

		Ft.	In.
Cowden	Deception Coal	2	2
,,	Cryne	2	6
,,	Mavis	2	8
,,	Great Seam	8	0
,,	Diamond	2	7
,,	Lilla Willie	5	1
,,	Blackbird Seam	3	11
,,	Coronation	3	10
,,	Hard Splint	3	3
,,	Smithy Coal	2	9
,,	Bryant's Splint	5	8
,,	Aleck's Coal	2	7
,,	Coal	2	6
,,	Little Splint	2	1
Cowden	Coal	2	1
,,	Parrot Seam	3	0
,,	Chalkieside Lime Coal	3	0

The Jewell seam, in the Mid Lothian section (Edinburghshire), 4 feet in thickness, and the Coronation seam, in the carboniferous limestone series, 3 feet 10 inches in thickness, both seams worked at Dalkeith, have been examined and reported upon in the "Third Report of Coals Suited to the Steam Navy," it being observed, during the experiments on these coals, "that they lighted easily, and burned freely, without the production of much smoke. They also required little stoking, and left but an inconsiderable quantity of incombustible matter."

* "Coal Fields of Great Britain," 4th edition, p. 305.

RESULTS TABULATED.*

Constituents.	DALKEITH.	
	Coronation Seam.	Jewell Seam.
Carbon	76·94	74·55
Hydrogen	5·20	5·14
Nitrogen	trace	0·10
Sulphur	0·38	0·33
Oxygen	14·37	15·51
Ash	3·11	4·37
Total	100·00	100·00
Yield of coke	53·5	49·8
Specific gravity	1·316	1·277
Weight of cubic foot of coal	55·16 lbs.	49·8 lbs.
Space occupied by one ton	43·36 c. f.	44·98 c.f.

The East Lothian Coal-field (Haddingtonshire), with an area of 30 square miles, possesses ten seams of coal of varying thickness. The strata in which they occur is carboniferous limestone, which completely encircles the coal-field on the east and south-east. The coal and ironstone of this area are regarded as the equivalents of the edge-coals of Mid Lothian. The following is a section of the coal series of East Lothian :—†

COAL SERIES OF EAST LOTHIAN.

		Ft.	In.
Coal "Great Seam"		7	0
Strata		50	0
Splint Coal		4	0
Strata	from 7 ft. to	18	0
Parrot Coal		1	8
Strata	from 7 ft. to	34	0
Three-foot Coal		2	6
Strata		9	0
Four-foot Coal	from 3 ft. 8 in. to	4	11
Strata		118	0
Five-foot Coal		4	0
Strata with Black Band Ironstone	about	130	0
Panwood Coal		1	6
Strata		72	0
Splint and Rough Coals (16 ft. apart)		4	0
Strata		100	0
Haughielin Coals (sometimes "Parrot Coal")	16 in. to	1	6
Strata		35	0

The above series repose on the Lower Limestone group, con-

* Report on Coal suited to the Steam Navy, p. 9.

† "Geology of the East Lothian Coal Field," by Messrs. Howell, Geikie, and Young, 1866, p. 57.

sisting of three principal beds of limestone. These limestones form a broad zone, encircling the coal-field on the east and south-east; and underneath occur the calciferous sandstones, rich in its fauna and flora.

Fifeshire Coal-field.—Situated on the north side of the Firth of Forth, for nearly a distance of 30 miles, but with a varying width, possesses some important seams of coal, and some anthracite, valuable for household purposes, gas manufacture, iron smelting, and steam purposes. In this coal-field occur 29 coal seams, having an aggregate thickness of 120 feet. Nearly the whole of the seams enter the sea between Kirkaldy and East Wemyss, and many of these are of high quality for the purposes above enumerated.

The following analyses exhibit generally the constituents of the coals examined and extensively raised in the Fifeshire coal-field. The first analysis refers to the "Fordell Splint Coal," from the colliery of the same name. The seam varies from 4 to 4½ feet in thickness, and is raised from the "Splint seam," at a depth of from 50 to 80 fathoms from the surface. This coal is described as hard, bituminous, and lively in burning, and when broken divides into rhombic fragments; spots of pyrites sometimes occur, but not in any considerable quantity. The second analysis, the "Elgin Wallsend," raised in the Balmule Colliery, a steam coal, resembles much in appearance the Fordell Splint, is described as a caking splint coal of cubical texture, burning freely with a strong flame. The third is an analysis of "Splint Coal," raised at the Wellwood Colliery, and used for raising steam and iron smelting:—*

Constituents.	FIFESHIRE COALS.		
	Fordell Splint Coal.	Balmule Elgin Wallsend.	Wellwood Splint Coal.
Carbon	79·58	76·09	81·36
Hydrogen	5·50	5·22	6·28
Nitrogen	1·13	1·41	1·53
Sulphur	1·46	1·53	1·57
Oxygen	8·33	5·05	6·37
Ash	4·00	10·70	2·89
Total	100·00	100·00	100.00
Yield of coke	52·03	58·45	59·15
Specific gravity	1·25	1·20	1.27

* Report on Coal suited to the Steam Navy, p. 9.

Clackmannanshire Coal-field.—This coal-field extends along the northern and eastern banks of the river Forth, and is in three divisions, separated by formidable faults. The southern portion is much exhausted; the middle area has long been, and still is, extensively worked, and the northern field is comparatively entire north of the river Devon. The following is a section of the coals, in descending order, at Old Sauchie:—*

	Ft.	In.
Coal	2	6
Three-foot Coal	3	0
Upper Five-foot	5	0
Four-foot Coal	4	0
Nine-foot Coal	9	0
McNish Coal	2	9
Mosie Coal	2	0
Lower Five-foot	5	0
Splint Coal	2	9
Coalsnaughton	4	6
Total	40	6

Ayrshire Coal-field.—This productive area is separated from the Clyde basin by the Dunlop Hills and rocks of trap of Devonian age. Much, however, of the minerals have been destroyed through the agency of intrusive, igneous masses and dykes of dolerite and basalt, which also interferes to a great extent with the prosecution of successful mining operations. The Girvan Valley, an important district, has an elongated coal-field about four miles long and half a mile broad, the greatest depth being probably 150 fathoms, embracing six seams of coal, of which much is already worked; these are:—

	Thickness.		
	Ft.	Ft.	In.
The Main Coal	10 to	12	0
Little Coal	3 ,,	4	0
Cannel Coal	3 ,,	5	0
Coral Coal		3	6
Craigie Coal		3	9
Rotten Coal		6	0

In the Dalmellington, Patna, and Littlemill districts, some extensive seams occur. At the Dalmellington Iron Works the Patna seams, three in number, and 21 feet thick, are chiefly used.

In the New Cumnock district some important seams are being wrought in a section at Colburn. There are nine seams, giving an aggregate thickness of 23 feet; and at Pathhead seven seams,

* Mr. John Geddes, M.E., Coal Commission Report, vol. i., page 76, 1871.

giving a thickness of 27 feet 11 inches. Other sections at Muirkirk and Lugar, important districts in the coal-field, give the following seams and thicknesses:—

MUIRKIRK.		Thickness. Ft.	In.	LUGAR.	Thickness. Ft.	In.
Coke Yard Seam		5	0	Ell Coal	3	0
Ell Coal		3	0	Main Coal	4	0
Splint Coal		2	4	Coal	3	6
Seven-foot Coal		8	0	Main Coal	4	0
Nine-foot Coal		9	4	Coal	2	4
Soft Coal		3	0	Mussel Coal	2	2
Catchyburn Coal	5 ft. to	9	0	Coal	2	7
Macdonald Coal		4	6	Coal	2	0

In the districts of Kilwinning, Dreghorn, and Kilmarnock, the section of coal is various; at Kilwinning, nine seams, of a total thickness of 21 feet 9 inches; at Dreghorn, 6 seams, 20 feet 7 inches; and at Kilmarnock, nine seams, 28 feet 7 inches in thickness; the Five-quarter coal, at Dreghorn, attaining a thickness of 4 feet 6 inches.

Of the coals of the Ayrshire coal-field, valuable alike for household purposes, for the manufacture of gas, and steam purposes, the annexed analyses of the coal raised at the Hurlford and Skerrington collieries of Messrs. Gilmour & Co., and at the Eglinton Colliery of Mr. Archibald Kenneth, show the respective composition of the Main seam in each colliery, as follows:—

Constituents.	Hurlford, &c.	Eglinton.
Carbon	79·82	80·08
Hydrogen	5·82	6·50
Nitrogen	·94	1·55
Sulphur	·86	1·38
Oxygen	11·31	8·05
Ash	1·25	2·44
Total	100·00	100·00
Yield of coke	49·30	54·94
Specific gravity	1·241	1·25

Lesmahago Coal Basin, a detached area seven and a half miles from east to west and from north to south, belonging to the carboniferous limestone series. It is said that three-fourths of this area is stored with coal of second-class quality, giving, at

Ponfrich, an aggregate thickness of 53 feet, enclosed in a vertical section of 1,200 feet of strata. Several valuable seams of coal occur in this area, the coal being in good request, owing to its large yield of gas for illuminating purposes. Analyses of the Lesmahago and other Cannel coals will be found at page 259.

Other small areas of coal occur at Canobie, in Dumfriesshire; at Campbeltown, in Argyleshire; at Brora, in Sutherlandshire; and in the Isle of Skye, all of considerable importance in their respective districts.

The Brora coal-field appears to have been worked as far back as the year 1598, when the first pit was opened by the then Countess of Sutherland; the coal of the Brora area, it is understood, was extensively wrought, at an early period, chiefly in connection with salt manufacture, and was discontinued about the year 1832, probably because of its ceasing to be profitable after the duty was taken off salt. The coal of Brora is of oolitic age; the seam is 3 feet 6 inches thick, and it is generally regarded as the only deposit of the kind worked. It is a valuable coal in that northern district of Britain, and is found to be constituted as follows, the analysis being made from an average sample:—

RESULTS TABULATED.

Fixed carbon	49·24
Volatile matter	26·50
Sulphur	6·40
Moisture	4·20
Ash	13·86
	100·20

When coked, it yields 62·90 per cent., the ash contained in coke amounting to 21·71 per cent.; sulphur, 5·08 per cent.; specific gravity of coal, 1·38; and the approximate heating power, ·685.

Production and Distribution of Coal.—The pages of the "Coal Commission Report" contain much interesting information, bearing on the early history of coal-mining in Scotland, of the Charters granted in successive reigns, from A.D. 1189, when the earliest record appears, of a grant to work coal to the Abbey of Newbattle by Sayer de Quinci, Earl of Winchester. Details are, however, absent showing the early development of the coal-fields

of Scotland. The earliest returns available, showing the number of collieries and the production of coal, commenced about the year 1854. Various estimates had appeared in previous years, prepared by experienced authorities conversant with the development of the coal-fields of Great Britain, but, at the best, they were but approximations. In the year 1854, Mr. Robert Williams, H. M. Inspector of Mines, made a careful inquiry, and found that 397 collieries were in active operation, winning coal, in that year, to the amount of 7,448,000 tons in Scotland. In the year 1855 there were 403 collieries, the output of coal amounting to 7,325,000 tons, showing a falling off, compared with the previous year, of 123,000 tons.

The great bulk of the production of 1855 was consumed in the numerous industries of Scotland. The blast furnaces reducing the ores of iron to a metallic state, consumed 2,152,800 tons; in the conversion of pig into malleable iron 367,200 tons were used; and in manufactures, steamboats, and the domestic consumption of Glasgow, 2,853,427 tons were employed, the remaining quantity, amounting to 1,951,573 tons, being distributed by railway and conveyed to ports of shipment for conveyance coastwise and for exportation, the former amounting to 530,971 tons, and the latter to 444,760 tons.

The coal-fields of Scotland are, for purposes of inspection, divided into an eastern and western division, the former under the inspection of Mr. Ralph Moore, and the latter under Mr. William Alexander. The following are the districts under the inspection of the above-named gentlemen, comprising coal areas in the shires named:—

EASTERN DIVISION.	WESTERN DIVISION.
Lanarkshire (East division).	Lanarkshire (West division).
Fifeshire.	Ayrshire.
Clackmannanshire.	Stirlingshire (West division).
Haddingtonshire.	Dumbartonshire.
Edinburghshire.	Renfrewshire.
Linlithgowshire.	Argyleshire.
Stirlingshire (East division).	Dumfriesshire.
Perthshire.	
Sutherlandshire.	

Following the growth of the coal industries of Scotland, since the year 1855, the annexed abstract shows the number of collieries and the output of coal in each inspection district:—*

* Reports of H. M. Inspectors of Coal Mines.

Year.	EASTERN DIVISION.		WESTERN DIVISION.	
	Number of Collieries.	Coal.	Number of Collieries.	Coal.
		Tons.		Tons.
1856	199	4,512,000	206	4,500,000
1857	210	4,598,000	215	5,613,473
1858	214	4,598,000	203	5,620,000
1859	219	4,750,000	194	5,550,000
1860	228	5,150,000	199	5,750,000
1861	226	5,225,500	198	5,855,000
1862	247	5,300,000	201	5,775,000
1863	270	5,250,500	212	5,850,000
1864	274	6,250,000	223	6,150,000
1865	274	6,400,000	223	6,250,000
1866	263	6,350,000	218	6,275,000
1867	263	7,897,368	218	6,228,575
1868	230	8,456,084	203	6,253,875
1869	211	7,879,500	201	6,537,650
1870	207	8,595,238	204	6,339,315
1871	216	8,883,926	204	6,564,365
1872	252	9,046,814	201	6,336,795
1873	260	10,142,039	239	6,715,733
1874	320	10,182,326	234	6,606,335
1875	334	11,419,619	232	7,177,888
1876	334	11,667,648	232	6,997,964
1877	305	11,452,373	222	6,867,701
1878	304	11,667,559	230	6,169,723
1879	361	11,300,567	312	6,169,360
1880	361	12,019,443	290	6,255,443

Summarising the above returns, the total coal produce of Scotland appears as follows in each year since 1855 :—

Year.	Number of Collieries.	Coal.	Year.	Number of Collieries.	Coal.
		Tons.			Tons.
1855	383	7,325,000	1868	433	14,709,959
1856	405	9,012,000	1869	412	14,417,150
1857	425	10,211,473	1870	411	14,934,553
1858	417	10,218,000	1871	490	15,438,291
1859	413	10,300,000	1872	453	15,383,609
1860	427	10,900,000	1873	499	16,857,772
1861	424	11,081,000	1874	554	16,788,661
1862	448	11,076,000	1875	566	18,597,507
1863	482	11,100,500	1876	566	18,665,612
1864	497	12,400,000	1877	527	18,320,074
1865	497	12,650,000	1878	534	17,837,282
1866	481	12,625,000	1879	673	17,469,927
1867	481	14,125,943	1880	650	18,274,886

For comparison, it may be stated that the total amount of coal raised in Great Britain, in the year 1856, was 66,645,500 tons, increased to 84,042,698 tons in the year 1860; ten years later, 110,431,192 tons; and in the year 1880 to 146,969,409 tons, or 75 per cent. increase in a period of twenty years.

Of the coal raised in Scotland, in the last three years, the following table shows the quantities raised in each of the principal coal-producing districts:—

Counties.	1878.	1879.	1880.
	Tons.	Tons.	Tons.
The Western District—			
Renfrew . . .	163,450	134,872	108,250
Argyle . . .	105,596	107,111	113,411
Ayr	3,184,429	3,203,052	3,106,965
Dumbarton . .	210,520	216,282	234,556
West Lanark . . .	2,253,660	2,250,504	2,399,840
West Stirling . .	252,068	257,539	292,421
The Eastern District—			
Clackmannan . .	273,213	271,664	268,090
Edinburgh . . .	725,122	758,371	793,804
Fife	1,676,901	1,726,701	1,930,511
Haddington . .	221,639	233,276	243,302
East Lanark . . .	7,683,595	7,135,416	7,627,159
Linlithgow . . .	394,721	464,823	448,955
East Stirling . . .	692,368	710,316	707,622
Total . . .	17,837,282	17,469,927	18,274,886

In the eastern division of the coal-fields of Scotland, the Inspector in his report for the year 1880 gives some particulars showing the proportion of coal raised by the two methods of working coal in his district, namely, the "Long Wall" and "Stoop and Room;" and remarks, that taking the quantities raised by each method, there were 26 per cent. less accidents by the "Stoop and Room" than by the "Long Wall" system. The total output of the district in 1880 was 12,019,443 tons, of which quantity 5,834,296 tons were obtained by the "Long Wall," and 6,185,147 tons by the "Stoop and Room" mode of working.*

Having thus far traced the output of the collieries in the eastern and western inspection districts, it will be interesting to summarise the returns and indicate the respective quantities produced in each county in Scotland in each of the above years, and, for comparison, the quantities raised in the year 1874; the details are as follows:—

* Reports of H. M. Inspectors of Mines, 1880, p. 192.

Counties.	1874.	1878.	1879.	1880.
	Quantities.	Quantities.	Quantities.	Quantities.
	Tons.	Tons.	Tons.	Tons.
Lanarkshire . .	9,461,682	9,937,255	9,385,920	10,026,999
Ayrshire . .	3,148,922	3,184,429	3,203,052	3,106,965
Fifeshire . .	1,390,678	1,676,901	1,726,701	1,930,511
Stirlingshire .	948,664	944,436	967,855	1,000,043
Edinburghshire	567,998	725,122	758,371	793,804
Linlithgowshire	454,566	394,721	464,823	448,955
Haddingtonshire	193,964	221,639	233,276	243,302
Dumbartonshire	141,988	210,520	216,282	234,556
Perth, Kinross, Clackmannan and Sutherlandshire	197,774	273,213	271,664	268,090
Renfrewshire .	181,678	163,450	134,872	108,250
Argyle and Dumfries .	100,749	105,596	107,111	113,411
Total . .	16,788,661	17,837,282	17,469,927	18,274,886

Mr. Ralph Moore, in his "Reports of the Eastern District of Scotland," gives some very interesting facts concerning the collieries in his inspection, and the production of coal, not only of the large companies, but also of individual firms. These facts appear in the annexed figures for the years 1874, 1878, and 1879, showing the number of mines of all kinds, shafts, collieries, pits, and companies working coal under the Coal Mines Regulation Acts, 1872, and the Metalliferous Mines Regulation Acts, 1875.

	1874.	1878.	1879.
	Nos.	Nos.	Nos.
Mines of all kinds	366	348	361
Shafts of all kinds . . .	744	695	686
Collieries	336	293	305
Coal pits	660	611	601
Companies working Coal . .	230	191	191

From these reports, the number of companies working coal shows that the collieries are gradually increasing in extent, and becoming larger. This is clearly apparent in the Inspector's returns for the years 1875 and 1876, which were as follows, showing that in the last-named year 25 companies, in the eastern district, raised upwards of 50 per cent. of the total production :—

1876.	TONS.	1875.	TONS.
1 firm raised over .	670,000	1 firm raised over .	630,000
1 ,, ,, . .	410,000	1 ,, ,, . .	440,000
3 firms ,, .	1,050,000	1 ,, ,, .	340,000
2 ,, ,, . .	500,000	3 firms ,, . .	900,000
1 firm ,, .	300,000	2 ,, ,, .	500,000
5 firms ,, . .	1,000,000	4 ,, ,, . .	800,000
7 ,, ,, .	1,050,000	7 ,, ,, .	1,050,000
5 ,, ,, . .	600,000	14 ,, ,, . .	1,680,000
22 ,, ,, .	1,760,000	18 ,, ,, .	1,440,000
34 ,, ,, . .	1,360,000	23 ,, ,, . .	900,000
135 ,, ,, .	5,900,000	144 ,, ,, .	5,760,000

The greatest quantity of coal, at this period, put out of a single shaft, was, in 1876, 136,000 tons, compared with 145,000 tons in the previous year, while the greatest quantity of coal put out of a pair of shafts in 1876 was 212,000 tons, compared with 210,000 tons in the previous year. In the year 1879 and previous year, the details under the same head were as follows :—

1879.	TONS.	1878.	TONS.
2 firms raised over	. 400,000 each	1 firm raised over	. 480,000
1 firm ,,	. 350,000	1 ,, ,,	. 450,000
2 firms ,,	. 300,000 each	2 firms ,,	. 350,000 each
2 ,, ,,	. 250,000 ,,	1 firm ,,	. 300,000
5 ,, ,,	. 200,000 ,,	2 firms ,,	. 250,000 each
8 ,, ,,	. 150,000 ,,	5 ,, ,,	. 200,000 ,,
7 ,, ,,	. 120,000 ,,	8 ,, ,,	. 150,000 ,,
18 ,, ,,	. 80,000 ,,	9 ,, ,,	. 120,000 ,,
39 ,, ,,	. 40,000 ,,	19 ,, ,,	. 80,000 ,,
107 ,, ,,	under 40,000 ,,	37 ,, ,,	. 40,000 ,,
		107 ,, ,,	under 40,000 ,,

Distribution of Coal.—Very full and complete information, showing the distribution of coal, sent coastwise and exported to foreign countries, appears in the Parliamentary Returns (annual) of coal, cinders, and culm. From these returns the following facts have been prepared, showing the quantities thus distributed before the year 1800 :—

Year.	Coastwise.	Exported.	Total.
	Tons.	Tons.	Tons.
1790	74,925	33,416	108,341
1791	82,446	36,679	119,125
1792	71,073	29,752	100,825
1793	67,396	20,062	87,458
1794	61,687	30,052	91,739
1795	56,014	20,107	76,121
1796	71,891	31,115	103,006
1797	52,745	19,431	72,176
1798	58,923	24,849	83,772
1799	52,029	11,838	66,863

The principal ports of shipment on the western coast of Scotland are Glasgow, Ayr, and Greenock. Irvine was also a shipping port of considerable importance from the year 1833 to the year 1864, since which latter year the port has disappeared from the list as a port of shipment. In the annexed abstract appear the aggregate quantities of coal shipped coastwise and exported from the western ports of Scotland in each of the years named:—

WESTERN PORTS OF SCOTLAND.

Year.	Glasgow.	Irvine.	Ayr.	Greenock.
	Tons.	Tons.	Tons.	Tons.
1830	3,167	5,847	...	12,102
1835	85,382	150,127	54,021	14,533
1840	112,245	272,102	91,638	28,094
1845	96,351	215,383	81,892	23,886
1850	108,306	264,087	72,264	21,382
1855	136,818	312,882	64,426	27,300
1860	159,989	497,118	66,863	63,805
1865	205,364	*280,616	126,597	92,684
1870	314,758	...	102,668	145,863
1875	599,706	...	279,499	248,368
1876	548,355	...	285,014	178,772
1877	586,379	...	332,686	162,320
1878	566,720	...	384,846	150,254
1879	528,105	...	362,530	137,435
1880	484,023	...	311,660	123,931

Turning to the ports on the eastern coast of Scotland, the more important of which are Grangemouth, Borrowstowness, Kirkcaldy, and Leith, all of which have, in a greater or less degree, contributed to the distribution, coastwise and to foreign countries, the following figures show the quantities sent away in each of the years named. The other ports shipping coal on the eastern coast are those of Dundee, Granton, and Alloa, while on the western coast, in recent years, Troon and Ardrossan have become important ports of shipment. The two last-named ports shipped the annexed quantities in the four years ending 1880:—

Year.	Troon.	Ardrossan.
	Tons.	Tons.
1877	551,045	247,005
1878	457,391	238,236
1879	502,476	287,867
1880	433,783	227,236

* Return for the year 1864.

EASTERN PORTS OF SCOTLAND.

Year.	Grangemouth.	Borrowstowness.	Kirkcaldy.	Leith.
	Tons.	Tons.	Tons.	Tons.
1830	1,670	15,344	2,550	2,872
1835	81,784	134,256	51,606	51,285
1840	92,487	169,947	63,137	42,959
1845	16,953	141,311	65,884	18,552
1850	26,373	116,991	84,943	13,843
1855	55,416	146,978	67,731	40,254
1860	64,208	276,327	117,597	42,289
1865	121,155	250,394	180,561	104,916
1870	111,490	293,308	264,971	117,494
1875	199,544	347,033	323,701	375,807
1876	207,051	386,599	342,302	336,611
1877	179,853	270,327	362,008	309,131
1878	174,526	277,249	431,103	201,276
1879	142,388	298,080	551,529	196,132
1880	126,883	325,153	545,925	215,404

The above figures indicate, in a decided manner, the development and distribution of the production of the collieries of Scotland during the past half century. Other ports, in late years, have contributed to increase the distribution of the coal, and in the following abstract, prepared from official returns, the total quantities of coal sent coastwise and to foreign countries appear. The same years as those in the two previous summaries have been selected for comparison, and side by side, as far as possible, the production of coal in Scotland has been given:—

Year.	Coastwise.	Exported.	Total.	Produce of Scotland.
	Tons.	Tons.	Tons.	Tons.
1830	...	47,080	...	...
1835	557,043	71,671	628,714	...
1840	723,534	156,792	880,326	...
1845	530,388	465,173	1,095,561	...
1850	463,123	336,453	799,576	...
1855	530,578	436,888	967,466	7,325,000
1860	743,214	653,432	1,396,646	10,900,000
1865	863,291	983,255	1,846,546	12,650,000
1870	1,061,586	1,338,127	2,399,713	14,934,553
1875	1,408,352	2,283,745	3,692,097	18,597,507
1876	1,307,296	2,335,660	3,642,956	18,665,612
1877	1,278,703	2,063,770	3,342,473	18,320,074
1878	1,325,617	1,918,954	3,244,571	17,837,282
1879	1,422,073	2,012,785	3,434,858	17,469,927
1880	1,215,816	1,935,333	3,151,149	18,274,886

In the last-named year, the total quantity of coal sent coastwise in the United Kingdom was 12,061,183 tons; that exported

to foreign countries, 16,442,296 tons; the declared value of the exported coal amounting to £7,206,799; the total output of the collieries of the United Kingdom amounting to 134,008,228 tons, an increase of 1,400,362 tons on the previous year.

Railway Distribution.—In the early returns of coal conveyed by railway in Scotland, all minerals, comprising coal, ironstone, iron ore, limestone, &c., were included. In the year 1854 the following statement shows approximately the quantities of coal carried by the Caledonian Railway, received at the stations named, and amounting to 251,932 tons; the total quantity of all kinds of minerals, including coals, forwarded by the system in the same year, being set down at 404,168 tons. The details of coal carried appear as under:—

STATIONS.	TONS.
Edinburgh	24,034
Glasgow	54,466
Greenock	54,024
Carlisle	4,751
Barrhead	49,163
Pollockshaws	10,982
Holytown	42,414
Greenhill	12,098
Total	251,932

It is not again until the year 1858 that returns are available; we then have the distribution of coal in Scotland for that year. The annexed statement shows the distribution under the respective heads; the total produce of Scotland in that year being 8,926,249 tons:—

HOW DISTRIBUTED.	TONS.
Consumed in ironworks	3,750,200
Exported coastwise	565,672
Exported to foreign countries	543,377
Consumed in manufactories	1,750,000
Employed in steam vessels	602,000
Employed in locomotives and railways	465,000
Colliery consumption and domestic use	1,250,000
Total	8,926,249

In the year 1867, and since, the coals carried by the several railway systems traversing the coal-fields have been regularly published; in this year the quantities carried were as follows:—

RAILWAYS.	TONS.
Caledonian	3,198,960
North British	2,739,940
Glasgow and South Western	1,738,787

Of the coal carried by the Caledonian railways, the coal-fields of Lanarkshire contributed 3,133,035 tons; Stirlingshire, 17,444 tons; and Renfrewshire, 48,481 tons; while of the coal conveyed by the North British railways, the great bulk was contributed by the Lanarkshire and Fifeshire coal-fields. Of the coal carried by the Glasgow and South-Western Railway, 897,999 tons were taken to the coast for shipment; 340,912 tons deposited at the several stations on the line; and 499,976 tons conveyed to ironworks.

In subsequent years, since 1869, the quantities by the several railways appear as follows:—

Year.	Caledonian.	North British.	Glasgow and South Western.
	Tons.	Tons.	Tons.
1869	4,023,209	3,907,064	1,690,207
1870	4,648,665	3,197,001	1,841,571
1871	5,014,894	3,600,618	1,937,177
1872	5,229,093	3,797,249	2,084,894
1873	5,305,060	4,016,351	2,163,263
1874	5,443,525	3,841,856	2,042,358
1875	5,942,943	4,558,098	2,335,294
1876	6,106,495	4,693,068	2,225,318
1877	6,646,254	4,682,128	2,446,585
1878	6,319,498	4,615,407	2,097,825
1879	5,983,056	5,375,494	2,537,576
1880	6,142,584	5,753,779	2,493,192

Comparing the above returns of the Caledonian Railway for the years 1870, 1878, and 1880, the annexed abstract will show the respective increase in each of the coal-producing districts traversed by this railway:—

Coal Fields.	1870.	1878.	1880.
	Tons.	Tons.	Tons.
Lanarkshire	4,400,585	5,988,915	5,736,794
Stirlingshire	17,732	61,545	81,599
Edinburghshire . .	173,991	88,135	122,016
Renfrewshire	566	9,508	1,237
Ayrshire	...	73,175	74,512
Linlithgowshire . .	...	65,048	86,770
Seaborne coal shipped inland . .	55,791	33,172	39,656
Total	4,648,665	6,319,498	6,142,584

The North British Railway exhibits in each of the same years an increase, though in a lesser degree than that of the Caledonian system. The details are as follows :—

Coal Districts.	1870.	1878.	1880.
	Tons.	Tons.	Tons.
Canobie. . . .	54,828	38,928	42,627
Fifeshire	944,483	1,339,225	1,639,094
Monklands . . .	1,636,299	2,556,363	3,252,810
Plashetts	46,934	20,294	12,962
The Lothians. . .	428,183	564,338	720,589
Other Collieries on Border Section .	86,274	96,259	85,697
Total coals carried	3,197,001	4,615,407	5,753,779

Following up the comparison in the distribution by the Glasgow and South Western Railway, the annexed statement shows the quantities retained for home use, and sent for shipment, in each year since 1869 :—

Year.	For Home Use.	For Shipment.
	Tons.	Tons.
1869	848,779	841,428
1870	944,170	897,401
1871	1,040,742	896,435
1872	1,095,281	989,613
1873	1,190,046	973,217
1874	1,129,806	912,552
1875	1,397,331	937,963
1876	1,308,305	917,013
1877	1,152,253	1,294,332
1878	939,758	1,158,027
1879	892,300	1,645,276
1880	927,537	1,565,655

Prices of Coal and Cost of Production.—In the western district of Scotland, in the year 1860, the average cost of getting a ton of coal did not exceed 2*s*. 8*d*. This did not include value of property, rent, and other charges. The average price per ton of coal at bank, in the same year, did not exceed 4*s*.; cartage, 6*d*. per ton per mile; railway charges, for short distances, 1*s*. per ton for six miles, and 1*d*. per mile for longer distances; the average price of coal in Glasgow at this period being about 8*s*. per ton. Since the "Coal Mines Regulation Act, 1872," has been in operation, the annual reports of the inspectors give many

valuable details on both points, more especially prices and wages. Mr. Ralph Moore, in charge of the eastern district of Scotland. in his Report for the year ending 1874, states that in the two preceding years there were periods of great prosperity in the mining industries. A decline, however, set in about the beginning of 1874, continuing to the end of the year, when prices reached nearly an ordinary rate. Thus the market price of screened coals in Glasgow, in December, 1873, was 16*s.* per ton, compared with 8*s.* 9*d.* per ton in December, 1874; dross, 6*s.* per ton, compared with 1*s.* 6*d.* per ton; miners' wages, in 1873, varying from 9*s.* to 10*s.* per day, compared with 5*s.* to 6*s.* per day in 1874; while the cost of hewing coal in 1873, in December and January, 1874, was 3*s.* 4*d.* per ton, declining to 1*s.* 10*d.* per ton in December of the same year.

Prices in 1876 were somewhat lower, coals, in Glasgow, being quoted at from 6*s.* 8*d.* to 7*s.* per ton; wages at this period being 4*s.* 6*d.* per day. Mr. Moore, in his Report for 1876, gives some interesting details of the wages of two miners in Lanarkshire, the one of an average man, the other of a first-class man.

The first worked 299 days in the year, and sent 1,026 tons of coal to bank, receiving wages amounting to £71 5*s.* 5*d.*, exclusive of deductions, giving an average rate of wages of 4*s.* 9*d.* per day. The first-class miner worked 300 days, sending 1,150 tons of coal to bank, receiving £88 13*s.* 3*d.* wages, also exclusive of deductions, giving an average rate of wages of 5*s.* 11*d.* per day.

Notwithstanding the steady decline of prices and wages, the production of coal has been steadily maintained. In the year 1878 the highest price of Ell or household coal, free on board at Glasgow, was 9*s.* 3½*d.* per ton; splint coal, 8*s.*; main coal, 7*s.* 4*d.*; the lowest prices being 6*s.*, 6*s.* 6*d.*, and 5*s.* 6*d.* per ton respectively. Comparing with prices in 1880, highest of Ell coal, per ton, 9*s.* 0*d.*; splint coal, 9*s.* 0*d.*; and main coal, 8*s.* 3*d.* per ton; the lowest prices being 6*s.* 9*d.* and 5*s.* 9*d.* These prices include the railway dues. The actual prices realised at the pit's mouth would be about 2*s.* 6*d.* per ton less than the above quotations.

Miners' wages in 1878, in the beginning of the year, were nominally 4*s.* 6*d.* per day, falling, as the year advanced, to 3*s.* 9*d.* and 3*s.* 6*d.* per day, while in 1879 the average wages varied from 3*s.* 3*d.* to 3*s.* 9*d.* per day.

In the annexed summary appears the average rate per day of miners' wages in each year since 1855 :—*

Year.	Miners' Wages.	Year.	Miners' Wages.
	s. d.		s. d.
1855	4 4	1867	4 9
1856	4 3	1868	3 9
1857	4 0	1869	3 9
1858	3 0	1870	4 0
1859	3 3	1871	4 6
1860	3 6	1872	7 3
1861	3 0	1873	8 6
1862	3 6	1874	6 6
1863	3 6	1875	5 0
1864	4 0	1876	4 6
1865	4 6	1877	4 3
1866	5 6	1878	3 3

Population employed in Coal-mining.—Previous to the year 1864, the information on this subject is more or less of an approximate character. In the year 1861, however, the Census returns show that in the eastern district of Scotland 18,091 persons were employed, and in the western district, in the same year, 17,795 persons, or a total of 35,886 persons employed in the collieries then in operation. In 1864, and subsequent years, the total number of male persons employed in the collieries of Scotland were as follows; † side by side, the total of coal raised in each year is given, and the average quantity raised per man :—

Year.	PERSONS EMPLOYED.			Coal Raised.	Average per Man.
	Eastern.	Western.	Total.		
	Nos.	Nos.	Nos.	Tons.	Tons.
1864	21,150	18,073	39,223	12,700,000	323
1865	21,150	18,375	39,525	12,800,000	324
1866	21,200	20,046	41 246	12,034,638	292
1867	29,000	21,075	50,075	14,125,943	282
1868	29,000	21,160	50,160	14,709,959	293
1869	28,000	20,007	48,007	14,637,043	305
1870	27,330	19,654	46,984	14,934,553	317
1871	27,300	19,561	46,861	15,438,291	329
1872	30,000	20,639	50,639	15,383,609	303

Since the passing of the "Coal Mines Regulation Act, 1872," which came into operation the following year, the numbers of

* Messrs. James Watson & Co., Glasgow.
† Returns of H.M. Inspectors of Coal Mines.

persons employed above-ground and under ground are separately given, distinguishing those engaged in coal mines from those employed in ironstone and shale workings. The numbers of persons working in coal mines, in the two districts of Scotland were as follows, with the total output of coal, and the average output per man in each of the same years :—

Year.	EASTERN.		WESTERN.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Nos.	Nos.	Tons.	Tons.
1873	29,880	5,854	19,365	3,426	58,525	16,857,772	288
1874	31,294	6,254	19,020	3,600	60,168	16,788,661	278
1875	29,321	6,080	17,507	3,489	56,397	18,597,507	330
1876	28,765	6,139	16,342	3,294	54,540	18,665,612	342
1877	27,422	5,798	15,516	3,332	52,068	18,320,074	351
1878	28,616	5,802	14,534	2,913	51,865	17,837,282	344
1879	29,289	5,831	14,899	2,812	52,831	17,469,927	330
1880	29,559	5,980	14,703	2,888	53,130	18,274,886	344

The returns of the number of persons employed in the coal mines of Scotland, in 1879, show an increase of 766 over 1878, although the quantity of coal produced shows a decrease of 367,355 tons. While comparing the average produce per man, an increase is shown from 1873 to 1877, since which date a falling off appears, due to strikes and restriction of output on the part of the miners. The respective ages of all persons employed in coal-mining in Scotland, in 1879, were as under :—*

All Ages.	EASTERN.		WESTERN.		Total.
	Under Ground.	Above Ground.	Under Ground.	Above Ground.	
	Nos.	Nos.	Nos.	Nos.	Nos.
From 12 to 13 . . .	224	2	119	...	345
" 13 to 16 . .	2,973	351	1,498	156	4,978
" 13 to 16 . . .	...	81†	...	9†	90†
Above 16 . . .	26,092	4,847	13,282	2,606	46,827
" 16	...	550†	...	41†	591
Total. . .	29,289	5,831	14,899	2,812	52,831

Resources and probable Duration of the Scotch Coal-fields.—Referring to the labours of the Royal Coal Commission, appointed in the year 1866 "to investigate the probable quantity of

* H.M. Inspectors of Coal Mines Report. † Females.

coal contained in the coal-fields of the United Kingdom, and to report upon the quantity of such coal which may be reasonably expected to be available for use," we have the following summary of results, showing the quantity of coal available for future use in the coal-fields of Scotland in 1870 :—*

SUMMARY.

	TONS.
Edinburgh	2,153,703,360
Lanarkshire	2,044,090,216
Fifeshire	1,098,402,895
Ayrshire	1,785,397,089
East Lothian	86,849,880
Firth of Forth	1,800,000,000
Dumfriesshire	358,173,995
West Lothian	127,621,800
Perthshire	109,895,040
Stirlingshire	106,475,436
Clackmannanshire	87,563,494
Dumbartonshire	48,618,320
Renfrewshire	25,881,285
Argyleshire	7,223,120
Sutherlandshire	3,500,000
Roxburghshire	70,000
Total	9,843,465,930

The total here arrived at is the quantity available to a depth of 3,000 feet. Taking the production of the Scotch coal-fields in the same year, amounting to 14,934,553 tons, and assuming the same annual average output, the coal-fields would not be exhausted for 660 years.

The total quantity of coal raised in Scotland during the ten years ending 1879 amounts to 174,293,288 tons; this, deducted from the original estimate of 1870, leaves 9,669,172,642 tons, which, at the average production of the past ten years (17,429,328 tons) would afford supplies for the next 555 years, a period short by 105 years of the estimated duration from the year 1870.

* Mr. John Geddes' Report, vol. i. "Coal Commission Report," p. 71.

CHAPTER XIX.

THE COAL-FIELDS OF IRELAND.

Description—Northern (Bituminous) Group—Counties of Leitrim, Tyrone, and Antrim — Analyses of Coal — Southern (Anthracitic) Group, Leinster and Munster—Analyses of Coal—Production of Coal—Population employed in Coal Mining—Resources of Coal-fields.

The Coal-fields of Ireland.—The coal deposits of Ireland are divided by Professor Hull into two groups, the line of demarcation being drawn from Galway Bay on the west to Dublin Bay on the east. The coal-fields north of this line produce coal of a bituminous kind, those of the southern area being anthracitic in character.

The northern coal-fields are those of Leitrim in Connaught, and Tyrone and Antrim in Ulster. The southern coal-fields extend through the counties of Clare, Limerick, and Cork, stretching both to the north and south of the estuary of the river Shannon, and the Leinster coal-field, the most important in the south of Ireland, occupying an extensive tract in the Queen's County, Kilkenny, and Tipperary.

But little can be said relative to the coal of Ireland as compared with the richer deposits of England and Scotland. The time was when Ireland was two-thirds covered with coal-beds; now only a few patches or outliers are left as evidences of former wealth, nearly all the coal measures having been denuded from the limestone and other "bases," leaving the great central limestone plain of Ireland beneath the drift, a now coal-less tract. The coal-fields already named being all that remains of what was once a widely-spread and extensive formation, the lower portion only being left. The total production of coal in Ireland in 1880 was but 133,702 tons, the greater proportion of which was anthracitic, compared with 128,560,821 tons in England and Wales, and 18,274,886 tons in Scotland.

The output of coal and ironstone in Ireland being so limited, a general sketch of the more important areas in which they occur,

and of the seams and bands of ironstone wrought, together with analyses, will here suffice, referring our readers to the authors and their works, which treat in detail of the mineral resources of Ireland.*

Northern Group of Coal-fields.—The bituminous coals, as previously stated, are found in the northern group of the coal-fields of Ireland; of these the several tracts of the Leitrim coal-fields are of considerable importance, those of Aughabehy, Arigna, and the coal-basin of Altygowlan, being the most important, the last-named coal-field being separated from the former by the river Arigna, and both coal-fields lying to the west of Loch Allen. The general succession of strata on this district is as follows:—

Lower Coal Measures.
Millstone Grit.
Yoredale Beds.
Carboniferous Limestone.

In a section of strata at Kilronan, some two miles south of Aughabehy, in the lower coal measures, occur three seams of coal, one of which, 18 inches thick, known as the "Top Seam," is most valued. Towards the top of the series of coal measures of a maximum thickness of 453 feet, shale occurs, varying in thickness from 100 to 200 feet, and in this shale are found numerous bands of ironstone of a similar kind to that found amongst the Yoredale beds below.

In a section of strata sunk at Arigna to a depth of 111 feet, when the main seam of coal, 2 feet 6 inches thick, was reached, the annexed shows the rocks passed through, with their respective thicknesses, the iron ore here being found within 3 feet of the surface.

SECTION OF STRATA AT ARIGNA COLLIERIES.†

	Ft.	In.
Surface	...	
Bed of iron ore	...	
Deep bog	15	0
Gravel	30	0
Slate	27	0
Rock	24	0
Slate	15	0
Coal seam	2	6

* "Industrial Resources of Ireland," by Sir Robert Kane, M.D., 1844. Second Edition; "Report on the Connaught Coal-fields (Arigna) Districts," by Sir Richard Griffiths, presented to the Royal Dublin Society, 1818.

† By W. J. Hughes, Esq., C.E., deposited in Mining Record Office. Museum of Practical Geology.

Analyses of the Coal.—Sir Robert Kane, who has examined several varieties of coal raised in this and other districts in Ireland, describes the Aughabehy coal as follows:—"A rich black coal, easily broken. Its specific gravity, 1·274. When heated it gives off a good deal of inflammable gas, and leaves a light, porous, grey, coherent coke." Another, the "Rover" Coal, is thus referred to:—"This coal is rather brown in aspect, and has a remarkable tendency to split into cubical fragments. The specific gravity is 1·287. When ignited it gives off gas, but does not froth. Its coke is porous, slightly coherent. It contains less foreign matter than any of the other kinds." The chemical composition of these coals is as follows:—*

RESULTS TABULATED.

Constituents.	Aughabehy.	Rover.
Carbon	79·69	81·04
Hydrogen	6·24	4·91
Oxygen	3·32	6·64
Ash	10·75	7·41
	100·00	100·00

It is thus seen that the Aughabehy is a much more bituminous coal than the Rover, which approaches nearer in its character to the anthracites of the south.

The Tyrone Coal-field.—Also producing bituminous coal, is situated north of the town of Dungannon in the county Tyrone, the village of Coal Island occupying the centre of the coal-field, a smaller district, the Annahone, having an area of above 320 acres. Mr. E. T. Hardman, of the Geological Survey of Ireland, who has examined this coal-field, observes, that although occupying but a small area, the coal measures are about 2000 feet thick, and contain from 22 to 24 seams, all of them of fair and some of them of excellent quality, varying in thickness from 10 inches to 9 feet.

Mr. Hardman gives the following section, showing the more important coals:—

* "Industrial Resources of Ireland," second edition, 1845, p. 24.

TABLE OF THE COALS AT PRESENT BEING WORKED.

Dungannon Coal Field.

		Ft.	In.
Middle Coal Measures (Coal Island series)	Annagher Coal	9	0
	Bone Coal	2	10
	Shining Seam	3	0
	Brackaville Coal	5	0
	Gortnaskea Coal (with 22 in. Cannel) .	6	0
	Beltiboy Coal	3	0
	Derry Coal . . . . . 3 6 to	5	0
	Yard Coal	3	0
Position uncertain .	Greenagh Coal (with 14 in. Cannel) .	4	6
Lower Coal Measures (Drumglass series) .	Main Coal of Drumglass . 4 10 to	6	0
	Lower ,, ,, . . 1 6 ,,	2	0

Mr. Hardman accompanies his paper by a series of analyses of the following seams :—*

LOWER COAL MEASURES.

No. 1. Main Coal or Drumglass Coal, Lurganboy (Top).
,, 2. Main Coal, Lurganboy (Bottom).
,, 3. Greenagh Soft Coal.
,, 4. Greenagh Cannel Coal.

MIDDLE COAL MEASURES.

No. 5. Derry Coal (Annagher Coal Island).
,, 6. Beltiboy Coal, Gortnaskea.
,, 7. Gortnaskea Coal.
,, 8. Annagher Coal (Brackaville).

ANALYSES OF THE COALS OF THE DUNGANNON COAL-FIELD.

Constituents	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 8.
Volatile matter . .	48·00	37·19	43·40	52·87	26·43	49·40	45·62
Coke { Fixed Carbon.	47·43	51·53	39·80	34·18	55·57	48·17	52·46
Coke { Ash . .	4·57	11·28	16·80	12·95	18·00	2·43	1·92
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Water at 212° F. . .	2·49	5·72	7·46	3·20	..	4·30	9·89
Sulphur . . .	2·90	1.65	1·94	1·94	..	1·52	2·56
Ash in Coke . . .	9·05	17·95	21·30	30·02	24·65	4·86	3·55
Specific gravity . .	1·295	1·385	1·452	1·396	1·499	1·266	1·250

The analysis of the Gortnaskea coal (No. 7) was only a partial one. The seam is six feet thick, including 22 inches of cannel at the top, the cannel giving 4·06 of ash, its specific gravity being 1·232. It is remarked of this coal that it is rare to find a cannel with such a small percentage of ash.

* "Proceedings of the Royal Irish Academy." Second Series, vol. ii., p. 529.

The above analyses give a very fair idea of the character of the coals of the Dungannon coal-field; and it will be seen that many of these bear favourable comparison with the best English coal in point of purity and heating power. They are all highly bituminous, and yield such a quantity of gaseous matter, that Mr. Hardman considers that any of them except the Derry Coal might be used with great advantage in Ireland for gas manufacture, with profit both to the colliery proprietor and the gas company.

The heating power of these coals is extremely high; 10 to 11 lbs. of water evaporated is considered very good work for 1 lb. of coal; nearly all the above give over 12 lbs., the best of them nearly 13 lbs.

Antrim Coal-field.—Situated at Ballycastle, at the northern extremity of Antrim, is found a small coal-field yielding coal of a bituminous character in quantities not exceeding a few thousand tons annually. It is recorded that the oldest colliery wrought in Ireland was at Ballycastle, where, during the year 1770, some miners exploring the levels broke through an old gallery, the walls of which were lined with stalactites, evidently of great age; and antique mining tools were found therein. The residents in the district had never heard of a tradition of the mine having been anciently worked, and the excavation therefore must have been made at a very remote period. About the year 1830 there were twelve coal-pits in this coal-field, four of which were then in operation, the coal seams being wrought to a considerable distance under the sea.

This coal-field is about four miles in length, and has an average width of 1½ miles. Professor Hull gives the annexed section of the coal series at Ballycastle Bay, as ascertained at the mines now at work, as follows:—

	Ft.	In.
Top or First Coal (Splint Seam)	3	0
Sandstones and shales	30	0
Second Coal (Hawksnest Seam)	3	0
Strata with black-band ironstone	240	0
Third Coal (Main Seam)	4	0
Strata with black-band ironstone below the main coal in some places)	60	0
Limestone	8	0
Strata (shales and sandstones)	240	0
Lower (black-band ironstone by boring)	1	0
Total	589	0

The coal of the Ballycastle coal-field is thus described by Sir Robert Kane :—" Dull, black in colour ; its specific gravity, 1·279. On ignition it gives out much gas, frothed very much, and left a porous coke." Its constituents are as follows :—*

Volatile matter	36·96
Pure coke	45·94
Ashes	17·10
	100·00

One part of it gave 25 of lead, hence 100 parts of it corresponded to 71·4 of pure carbon. The coal is considered in its economical relations suitable for industrial purposes of all kinds where coal is employed.

Southern Group of Coal-fields.—The most important in the south of Ireland, yielding anthracite, is that of Leinster, comprising a great area of the county of Kilkenny, Queen's County, and a part of Carlow. A portion of the same coal-field extends into the county Tipperary, and is separated from the Kilkenny coal-field by an intervening neck of limestone. The Leinster coal-field is some 20 miles in length between Ballyroan on the north, and Gowran on the south, its greatest width at Castlecomer being about 14 miles. The isolated coal-field of Tipperary extends about 20 miles in length from Freshford to near Cashel, and is about six miles wide, the towns of Killenaule and New Birmingham occupying its centre. The following is given by Professor Hull as the general series of coal in the Castlecomer coal-basin. Some measures of ironstone also occur.†

	Ft.	In.
Uppermost beds about	12	0
Peacock Coal	1	10
Strata	45	0
Stony Coal	3	0
Strata	21	0
Double Seam	5	0
Strata and shales	120	0
Three-foot or Old Colliery Coal	3	0
Strata	180	0
Five-foot Coal	3	6
Strata	300	0
Upper and Lower Towlerton Coals . . 1ft. 6in. to	2	0
Flag series, about	650	0
Black Shale series	500	0
Upper Carboniferous Limestone		

* "Industrial Resources of Ireland," second edition, p. 26.

† "Coal-fields of Great Britain," 4th edit., p. 327.

Analyses of the Coal.—The coal of the Slievardagh coal-field in the County Tipperary reported upon * is described as highly anthracitic. The specimen examined was obtained from the 3 feet vein at a depth of 25 yards from the surface, the vein itself having an inclination of 1 in 5, and situate in soft shale and sandstone, both easily worked. The mean composition of this coal is as follows per cent. :—*

RESULTS TABULATED.

Carbon	80·03
Hydrogen	2·30
Nitrogen	0·23
Sulphur	6·76
Oxygen, Ash	10·80
	100·12
Specific gravity	1·59
Coke per cent.	90·10

The average weight of a cubic foot of this coal is 62·8 lbs.; the space occupied by one ton 35·66 cubic feet; while 1 lb. of the coal will evaporate 9·85 lbs. of water from a temperature of 212° Fahr.

The coal of the Slievardagh district is worked by the Mining Company of Ireland, who raised 25,276 tons of anthracite in 1879, compared with 28,503 tons in 1880.

Sir Robert Kane,† who has examined specimens of the following coals raised in the Leinster and Munster coal-fields—

The Rushes Coal, Queen's County;
The Pollough Coal, Castlecomer;
The Sweet Vein, Kanturk, Munster—

remarks that "the anthracites have no tendency to froth or cake in coking. They give off little or no inflammable gas on being ignited, but usually the masses break up quite small, especially if the heat be suddenly applied. The ashes are almost always red, owing to oxide of iron remaining after the combustion of the pyrites, which the anthracite usually contains."

By the ordinary analysis for carbon and ash these coals yielded:—

* First Report, "Coals suited to the Steam Navy," p. 12.

† "Industrial Resources of Ireland," 2nd edition, p. 27.

Constituents.	Rushes.	Pollough.	Sweet Vein.
Volatile matter . .	9·85	10·40	10·35
Pure Carbon . . .	86·42	79·71	81·13
Ashes	3·73	9·89	8·52
	100·00	100·00	100·00

The pure anthracite of the same veins considered separately from ashes and sulphur giving the annexed results :—

Constituents.	Rushes.	Pollough.	Sweet Vein.
Carbon	93·53	92·37	94·39
Hydrogen	3·63	2·40	4·05
Oxygen	2·84	5·23	1·56
	100·00	100·00	100·00

The Rushes coal is generally considered as representing the usual composition of these varieties of coal.

The Munster Coal-field.—In this coal-tract is comprised a considerable area of the counties of Clare, Limerick, Cork, and Kerry; and in each of these counties coal has been discovered and worked, the most important localities being situated between the River Blackwater and Kanturk in the County Cork. The coal lies in a series of troughs, the hills usually striking from east to west, the strata dipping on either side north and south at considerable angles, often perpendicular. Sir Richard Griffiths gives the number of coal seams in this coal-field as six; of these, three of the most valuable are locally known as the Bulk Vein, Rock Vein, and the Sweet vein. Coal has been extensively worked in the Barony of Dunhallow, County Cork, also in Clare, but the seams of coal in the latter county, although extending over large areas, are comparatively thin, and the character of the coal is softer and more slaty than that obtained in the Kilkenny and Tipperary districts. On the contrary, the seams in the Dunhallow district, County Cork, vary from two to three feet in thickness, and produce anthracite of an excellent description. Analyses of these coals will be found with those of other coals in the Tipperary extension of the Leinster coal-field.

Production of Coal.—The total production of the Irish coal-fields is shown in the subjoined table, distinguishing the anthracitic and bituminous coal to the end of 1868:—

Year.	Collieries.	Anthracite.	Bituminous.	Total Coal.
	Nos.	Tons.	Tons.	Tons.
1856	22	96,220	40,415	136,635
1857	45	80,420	40,210	120,630
1858	47	79,500	41,250	120,750
1859	45	78,250	42,150	120,300
1860	46	70,250	49,175	119,425
1861	46	72,570	50,000	123,070
1862	46	73,000	54,500	127,500
1863	46	72,550	54,500	127,050
1864	41	70,000	55,000	125,000
1865	39	70,000	53,500	123,500
1866	39	68,750	55,000	123,750
1867	34	75,000	50,000	125,000
1868	34	74,500	52,450	126,950

From 1869 to 1880 the total quantity of coal raised is alone given, the separation of the two varieties not being satisfactory:—

Year.	Collieries.	Total Coal.	Year.	Collieries.	Total Coal.
	Nos.	Tons.		Nos.	Tons.
1869	33	127,923	1875	53	127,950
1870	32	141,470	1876	55	124,936
1871	30	165,750	1877	49	138,722
1872	29	103,435	1878	50	121,975
1873	34	103,465	1879	47	129,000
1874	42	139,218	1880	30	133,702

Population employed in Coal Mining in Ireland.—In 1873 the total number of persons engaged in coal-mining amounted to 1,950, of whom 1,209 were engaged under, and 741 above ground. The details of recent years ending 1880 appear in the annexed summary:—*

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	1,209	741	1,950	135,731	79
1874	1,120	531	1,651	139,213	84
1875	1,069	475	1,544	128,207	83
1876	946	419	1,365	125,195	90
1877	883	365	1,248	140,181	112
1878	841	381	1,222	122,051	100
1879	819	296	1,115	129,003	115
1880	777	294	1,071	133,702	124

* Reports of H.M. Inspectors of Mines.

In each of the same years the quantity of coal raised in each of the four provinces of Ireland was as follows, also the number of persons employed in each province :—

Year.	CONNAUGHT.		ULSTER.		LEINSTER.		MUNSTER.	
	Nos.	Coal.	Nos.	Coal.	Nos.	Coal.	Nos.	Coal.
		Tons.		Tons.		Tons.		Tons.
1873	·376	11,021	391	18,105	777	61,425	406	45,180
1874	111	5,108	321	17,810	828	73,302	391	43,993
1875	84	4,772	261	15,869	866	66,876	333	40,684
1876	99	5,203	183	15,335	798	72,025	285	32,632
1877	78	6,477	180	15,398	713	88,095	277	30,211
1878	75	6,456	217	12,407	663	74,474	267	28,714
1879	88	9,600	165	17,066	624	77,061	238	25,276
1880	87	8,506	175	21,203	589	75,490	220	28,503

Resources of the Coal-fields of Ireland.—The investigation as to the quantity of coal remaining in the coal-fields of Ireland by the Royal Coal Commission was entrusted to the late Mr. J. B. Jukes, F.R.S.; on that gentleman's decease, Professor Hull, who succeeded him as Director of the Geological Survey of Ireland, continued the inquiry with the assistance of Messrs. G. H. Kinahan and J. O'Kelly, officers of the survey. In the tabulated statement annexed showing the total quantities of coal unworked, and the net tonnage available for future use, the respective quantities are thus distributed amongst the several coal-fields :—*

Districts.	Coal Unworked.	Coal available for use.
	Tons.	Tons.
1. Ballycastle, County Antrim .	18,000,000	16,000,000
2. Tyrone (visible and concealed) .	36,950,000	32,900,000
3. Queen's County, Kilkenny, and Carlow (Leinster) . . .	86,202,000	77,580,000
4. Tipperary	29,500,000	25,000,000
5. Clare, Limerick, and Cork (Munster)	23,000,000	20,000,000
6. Connaught (Arigna district) .	12,000,000	10,800,000
Totals	205,652,000	182,280,000

Taking the net tonnage of coal available for use and deducting therefrom the production of the ten years ending 1879, amount-

* "Coal Commission Report," vol. i., p. 78.

ing to 1,295,921 tons, there remains for future use 180,984,079 tons. Of the coal thus available it is generally assumed that the proportion of anthracite is two-thirds, that of bituminous coal being about one-third of the total quantity.

Prices of Coal at the Pit Mouth.—The prices of coal in the years 1879 and 1880 show but little variation; the average may be taken as about 11*s*. 10*d*. per ton—the highest price of anthracite £1 3*s*. 4*d*., the lowest of bituminous coal 6*s*. 8*d*. per ton; the coal of the Leitrim district varying from 5*s*. to 10*s*. per ton. The Ballycastle district in the County Tyrone, slack, 4*s*.; coal, 10*s*. per ton. In the Leinster district slack sold for 5*s*., and coal 15*s*. to 20*s*. per ton; the highest prices quoted being the produce of the collieries of the Mining Company of Ireland, situated in the Slievardagh district, 75 per cent. of their coal averaging in prices from 5*s*. to 8*s*. 4*d*. per ton, the remainder from 15*s*. to 23*s*. 4*d*. per ton in 1880.

CHAPTER XX.

THE COAL-FIELDS OF THE UNITED KINGDOM.

General Summary—Areas of Coal-fields—Production of England, Wales, Scotland, and Ireland—Distribution of Coal by Railway—Coal brought into London—Coal sent Coastwise and exported to Foreign Countries—Population employed in Coal Mining—Resources and probable duration of Coal-fields.

General Summary.—Having previously considered each coal-field in the United Kingdom, it only remains to summarize all available information under the following heads:—

I. Areas of the Coal-fields of the United Kingdom:—

COAL-FIELDS.			AREA IN SQUARE MILES.
England,	Durham and Northumberland		796
,,	Yorkshire, Derbyshire and Nottinghamshire		800
,,	Cumberland		25
,,	Lancashire and Cheshire		220
,,	Leicestershire		15
,,	Warwickshire		30
,,	Shropshire		28
,,	North Staffordshire		75
,,	South Staffordshire		93
North Wales,	Anglesea, Denbighshire, Flintshire		90
South Wales,	Monmouthshire	104	
,,	Glamorganshire	518	
,,	Brecknockshire	74	1,000
,,	Caermarthenshire	228	
,,	Pembrokeshire	76	
Gloucestershire (Forest of Dean)			34
Somersetshire (Bristol)			150
Scotland			1,720
Ireland			2,800*
	Total Area		7,876

II. Production of Coal in Great Britain.—Towards the close of the past century and previously, from careful estimates appearing in the pages of the Report of the Coal Commission, it is shown that the total production of the collieries of the kingdom in each of the following years amounted to:—

* Estimated area.

YEAR.	QUANTITIES.
1660	2,148,000 tons.
1700	2,612,000 ,,
1750	4,773,000 ,,
1770	6,205,400 ,,
1780	6,424,976 ,,

At this period the Durham and Northumberland coal-field furnished 25 per cent. of the total production. In the year 1785, and until the year 1800, the output of the collieries of the United Kingdom is given approximately as follows:—

YEAR.	QUANTITIES.
1785	6,888,712 tons.
1790	7,618,760 ,,
1795	10,681,728 ,,
1800	10,080,300 ,,

Advancing to the year 1816, it appears from evidence given before a Committee of the House of Lords, appointed to take into consideration the state of the coal-trade of the United Kingdom,* and on the authority of the eminent engineer, Mr. Buddle, that the quantity carried by canals and railways, in different parts of the kingdom, amounted to 4,078,508 chaldrons (the Newcastle chaldron being 53 cwt.).

The total production of the kingdom for the same year (1816), as given by Samuel Salt, in his "Statistics and Calculations," amounted to 27,020,115 tons, in the following details:—

COAL FIELDS.	TONS.
Yorkshire	2,563,626
Derbyshire	942,218
Nottinghamshire	494,665
Leicestershire	176,665
Warwickshire	431,849
Staffordshire	795,000
Quantity that passed towards the Eastern seas	5,404,023
Quantity believed to pass towards the Western seas	5,404,023
Quantity carried by canal and railway	10,808,046
Total production in 1816	27,020,115

Between 1816 and 1854 many returns are met with, chiefly estimates of the probable quantities raised; in the last-named year, however, the annexed return appears, showing the quantity of coal raised from the 2,397 collieries then in operation in the United Kingdom, producing 64,661,401 tons. The details of production are as follows:—

* Report of Select Committee, House of Lords, dated 15 June, 1829.

Coal-fields.	Number of Collieries.	Production of Coal.	Coal-fields.	Number of Collieries.	Production of Coal.
England—		Tons.			Tons.
Northumberland and Durham	225	15,420,615	Brought forward	1,617	45,929,285
			England—continued		
Cumberland	23	887,000	Gloucestershire		
Yorkshire	276	7,260,500	Somersetshire	87	1,492,366
Derbyshire	123	2,406,696	Devonshire		
Nottinghamshire	17	813,474	*Wales*—		
Warwickshire	15	255,000	Anglesea, Flintshire, and Denbighshire	60	1,143,000
Leicestershire	11	439,000	Monmouthshire		
Staffordshire and Worcestershire	516	7,500,000	Glamorganshire	246	8,500,000
Lancashire	333	9,080,500	Pembrokeshire		
Cheshire	30	786,500	*Scotland*	368	7,448,000
Shropshire	48	1,080,000	*Ireland*	19	148,750
Carried forward	1,617	45,929,285	Total	2,397	64,661,401

Since the year 1854 the production of coal, with the number of collieries, has been as follows, the produce of England, Wales, Scotland, and Ireland being separately distinguished, the output increasing upwards of two-fold since 1854.

STATEMENT SHOWING THE PRODUCTION OF COAL IN THE UNITED KINGDOM SINCE 1854:—

* Including production of Monmouthshire.
† Including 4,000,000 tons wasted on fire-heaps.
‡ Including 2,404,000 tons wasted on fire-heaps.

Following the production of the coal-fields of the United Kingdom, the annexed details for the years 1860, 1870, and 1880, afford the required data for comparison, showing the output of the collieries of each coal-field in the years given:—

Coal Fields.	1860.	1870.	1880.*
	Tons.	Tons.	Tons.
England—			
Northumberland, North and South Durham . . .	18,244,708	27,613,539	34,913,508
Cumberland	1,171,052	1,408,235	1,680,841
Westmoreland	...	...	1,950
Cheshire	750,500	929,150	681,000
Lancashire, North and East; Lancashire, West . .	11,350,000	13,810,600	19,120,294
Yorkshire, North Riding . .	...	...	5,270
,, West Riding . .	9,284,000	10,606,604	17,468,536
Derbyshire	4,940,000	5,102,265	7,903,834
Nottinghamshire . . .		2,115,372	4,432,393
Warwickshire	545,000	647,540	1,101,386
Leicestershire	730,000	599,450	1,063,382
Staffordshire, North and South, and Worcestershire .	7,648,300	13,230,062	13,734,800§
Shropshire	850,500	1,343,300	905,000
Gloucestershire, Somersetshire	†5,503,400	1,955,910	1,953,732
Monmouthshire	...	4,364,342	5,039,549
Wales, North—			
Flintshire, Denbighshire . .	1,750,500	2,329,030	2,429,315
Wales, South—			
Glamorganshire, Brecknockshire, Pembrokeshire, and Carmarthenshire .	6,254,813	9,299,770	16,126,031
Scotland—			
Eastern District . . . ; Western District . . .	10,900,500	14,934,553	18,274,886
Ireland	119,425	141,470	133,702
Total of the United Kingdom	‡84,042,698	110,431,192	146,969,409

III. Distribution of Coal by Railway.—Hitherto the quantities of coal carried from our several coal-fields by Railways have received attention; it is now desirable to follow up this inquiry by ascertaining the total quantities of coal carried by each of the great railway systems, giving the aggregate in each year, and with this view the following tables have been prepared, commencing with—

No. 1. North Eastern Railway System:—

* According to returns of H.M. Inspectors of Mines, 1880.

† Including the produce of Monmouthshire.

‡ Including 4,000,000 tons wasted on fire heaps.

§ Including 1,429,000 tons the produce of Worcestershire in 1880.

Year.	From Durham and Northumberland.	From Lancashire and Yorkshire.	Total.
	Tons.	Tons.	Tons.
1854	2,571,064	338,777	2,909,841
1855	2,547,931	312,369	2,860,300
1856	1,753,045	287,144	2,040,189
1857	2,554,330	357,656	2,911,986
1858	2,402,011	341,375	2,743,386
1859	2,383,765	334,835	2,718,600
1860	2,575,303	412,097	2,987,400
1861	2,650,430	403,825	3,054,255
1862	3,826,590	391,097	3,217,687
1863	4,866,393	361,860	5,228,253
1864	5,744,501	456,320	6,200,821
1865	7,069,556	469,080	7,538,636
1866	7,350,956	527,887	7,878,843
1867	7,503,152	572,808	8,085,860
1868	7,357,266	606,688	7,963,954
1869	8,280,310	675,378	8,955,688
1870	8,999,784	866,422	9,866,206
1871	10,089,217	1,064,407	11,153,625
1872	10,486,168	1,134,543	11,620,711
1873	10,792,280	1,067,651	11,859,931
1874	10,689,846	1,105,021	11,794,867
1875	11,032,299	1,281,248	12,313,547
1876	10,535,438	1,240,645	11,776,083
1877	10,439,768	1,318,887	11,758,655
1878	9,907,829	1,344,318	11,252,147
1879	9,320,511	1,455,895	10,776,406
1880	11,661,676	1,583,942	13,245,618

The extent of the distribution of the Durham and Northumberland coal appears in the annexed statement showing the details of its movement in each of the years named :—

Distribution.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
The quantity of Coal carried over the North-Eastern Railway for local consumption and land sale from the Durham and Northumberland Coal Fields, and which was distributed over the districts Berwick and Kelso in the North, Carlisle and Tebay in the West, and Leeds, Knottingley, Doncaster and Altofts in the South	1,673,278	4,907,714	5,935,937
Shipped at Hull, Coal . . .	98	...	101
For North-Eastern Company's use	43,780	362,866	610,364
The quantity of Coal passed over the North-Eastern Railway to districts			
Carried Forward . . .	1,717,156	5,270,580	6,546,402

Distribution.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
Brought Forward . . .	1,717,156	5,270,580	6,546,402
South of Altofts, Knottingley, Doncaster and Leeds, and also of Coal to places North of Kelso and Berwick, and West of Morpeth, Hexham, Carlisle, and Tebay, being the entire through traffic of Coal . . .	149,552	703,715	398,257
The quantity of Coke carried over the North-Eastern Railway for local consumption and land sale between Kelso and Berwick in the North, Carlisle and Tebay in the West, and Leeds, Knottingley, Doncaster, and Altofts in the South . . .	145,722	1,909,442	2,780,148
Shipped at Hull, Coke . . .	166	93	31
For North-Eastern Company's use, Coke.	169,870	128,276	7,012
The quantity of Coke carried over the North-Eastern Railway to districts South of Altofts, Doncaster, Knottingley and Leeds, and to places North of Kelso and Berwick, and North and West of Morpeth, Hexham, Carlisle and Tebay, being the entire through traffic of Coke . .	392,837	987,678	1,929,826
Total carried, Coal and Coke .	2,575,303	8,999,784	11,661,676

The distribution of coal, the produce of Yorkshire and Lancashire collieries, in each of the same years, was as follows, over the North Eastern Railway system :—

Distribution.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
The quantity of Coal carried over the North-Eastern Railway from Yorkshire and Lancashire Collieries for consumption at places on the North-Eastern Railway	354,385	663,474	*952,764
For shipment at Hull, Coal . .	57,502	184,602	572,835
Do. Do. Coke .		2,001	419
Do. at Goole, Coal . .		11,778	57,031
Do. at Selby, Coal .	210	4,567	893
Total Coal and Coke . .	412,097	866,422	1,583,942

* This quantity includes 203,560 tons carried for consumption to places off the North-Eastern system.

No. 2. Midland Railway System.—From the following returns since the year 1856, a remarkable development of the coal industries of those districts traversed by the system, appears, showing a five-fold increase.

Coal carried by the *Midland Railway System* in each year since 1856 :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1856	2,449,552	1869	6,532,521
1857	2,525,751	1870	7,370,987
1858	2,695,584	1871	8,255,469
1859	3,158,020	1872	8,963,170
1860	4,001,270	1873	9,891,661
1861	4,048,071	1874	9,615,186
1862	3,738,833	1875	10,627,117
1863	4,330,022	1876	10,057,896
1864	5,198,890	1877	10,384,244
1865	5,470,735	1878	11,063,877
1866	5,521,180	1879	12,078,084
1867	5,927,004	1880	12,383,910
1868	5,822,494		

The annexed details of quantities carried by the Midland system in 1860, 1870, and 1880, exhibits clearly the increase in the movement of coal in each of those years :—

Coal Districts.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
Derbyshire } Nottinghamshire }	2,230,275	4,079,447 471,118	5,603,872 1,614,377
Yorkshire	483,693	1,382,808	2,408,650
Leicestershire	717,633	966,830	1,066,861
Gloucestershire } South Wales }	227,275	219,010 4,730	223,098 660,872
Durham	255,163	112,801	147,692*
South Staffordshire } Warwickshire }	80,104	42,305 75,863	189,247* 308,697
Lancashire	7,127	16,075	130,216*
Somersetshire	...	...	19,626*
Cumberland	...	...	8,345*
Scotland	...	...	2,357*
Total	4,001,270	7,370,987	12,383,910

No. 3. London and North Western Railway.—The earliest return available, for the year 1854, shows that a total quantity

* Quantities received from other lines and carried over Midland system.

of coal was carried by this system, amounting to 1,960,238 tons; since 1856 the quantities have been as follows:—

LONDON AND NORTH WESTERN RAILWAY.

Year.	Coal Carried.	Year.	Coal Carried.
	Tons.		Tons.
1856	2,241,541	1870	7,165,371
1857	2,468,451	1871	7,755,657
1859	2,721,000	1872	8,193,991
1862	2,861,667	1873	8,299,491
1863	3,756,111	1874	7,541,425
1864	3,179,910	1875	9,077,654
1865	6,032,578	1876	9,496,171
1866	4,639,461	1877	9,687,999
1867	5,887,003	1878	9,701,965
1868	5,658,071	1879	10,828,393
1869	6,488,207	1880	11,100,891

The details of the quantities carried in the years 1860, 1870, and 1880, from the coal-fields traversed by the London and North Western system being as follows:—

Coal-fields.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
Lancashire	1,411,000	4,967,785	7,024,080
South Staffordshire	94,000	665,720	1,511,099
South Wales	219,000	70,321	903,335
North Wales	...	376,512	304,509
Warwickshire	54,000	187,931	306,252
Yorkshire	108,000	203,205	236,648
Cheshire	160,000	104,484	184,815
North Staffordshire	...	60,833	79,595
Shropshire	...	117,317	106,333
Leicestershire	...	...	44,838
Derbyshire	675,000	66,217	27,632
Cumberland	...	345,046	371,755
Total .	2,721,000	7,165,371	11,100,891

No. 4. The Great Northern Railway.—Commencing with the year 1857, when the total weight of coal carried by this system amounted to 968,125 tons; the quantity carried from Yorkshire was 895,767 tons, and from Derbyshire, 72,358 tons. Since 1857 the quantities carried are as follows:—

GREAT NORTHERN RAILWAY.

Year.	Coal Carried.	Year.	Coal Carried.
	Tons.		Tons.
1857	968,125	1870	2,276,312
1860	985,588	1871	2,403,926
1861	1,076,673	1872	2,553,051
1862	1,068,917	1873	2,545,278
1863	1,148,681	1874	2,307,024
1864	1,751,105	1875	2,696,645
1865	2,097,809	1876	2,658,102
1866	2,212,893	1877	2,873,158
1867	2,343,755	1878	2,992,642
1868	2,113,290	1879	3,475,343
1869	2,121,541	1880	3,627,756

The total weight carried from each coal-field in the years 1860, 1870, and 1880, by the Great Northern Railway, will be seen in the annexed table :—

Coal-fields.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
Durham	...	524,695	210,083
South Yorkshire	181,560	551,348	863,575
West Yorkshire	611,112	443,261	971,074
N. and S. Lincolnshire	...	...	161,860
Derbyshire	159,412	573,261	896,636
London N. Western	...	...	35,917
North Staffordshire	...	...	13,547
South Wales	...	...	23,550
Leicestershire	...	6,561	1,829
Retford	33,504	177,186	*449,685
Total	985,588	2,276,312	3,627,756

No. 5. The Great Western Railway.—The total quantity of coal carried in the year 1857 was 382,104 tons, from the following coal districts :—

	TONS.
South Wales	120,080
North Wales	93,985
Vale of Neath	24,772
Radstock	143,267
Total	382,104

The total quantities carried in later years being as follows :—

* Carried to London and North-Western Railway *viâ* Market Harborough.

Year.	Coal Carried.	Year.	Coal Carried.
	Tons.		Tons.
1857	382,104	1873	5,411,105
1860	542,199	1874	5,546,865
1862	713,501	1875	5,469,506
1865	2,182,739	1876	6,053,806
1869	3,683,640	1877	6,412,798
1870	3,791,532	1878	5,938,534
1871	3,962,647	1879	6,481,342
1872	4,296,597	1880	6,909,968

The coal thus carried in the years 1860, 1870, and 1880, was derived from the following coal-fields traversed by the Great Western Railway system :—

Coal-fields.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
South Wales . . . . . Forest of Dean . . . . Vale of Neath	204,082	2,850,412	5,384,411
North Wales	122,530	646,810	960,934
Radstock	185,363	294,310	258,482
Bristol	30,224	...	...
South Staffordshire . . .	...	...	306,141
Total .	542,199	3,791,532	6,909,968

No. 6. Taff Vale Railway.—Total quantities of coal and coke conveyed over the Company's lines in each year since 1841 :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1841	41,669	1861	2,297,250
1842	114,516	1862	2,540,657
1843	152,100	1863	2,722,011
1844	187,740	1864	2,842,049
1845	265,040	1865	2,855,138
1846	294,175	1866	3,248,235
1847	360,324	1867	3,381,045
1848	502,029	1868	3,540,324
1849	530,145	1869	3,310,067
1850	594,222	1870	3,943,661
1851	612,716	1871	3,593,932
1852	711,692	1872	4,213,506
1853	874,362	1873	4,527,641
1854	1,025,145	1874	4,352,778
1855	1,155,904	1875	3,776,813
1856	1,394,394	1876	4,879,150
1857	1,468,527	1877	5,170,953
1858	1,445,157	1878	5,613,639
1859	1,759,422	1879	5,849,184
1860	2,132,995	1880	6,894,403

This railway, though inconsiderable in extent compared with the several systems previously referred to, exercises an important influence in the movement of coal in the eastern extremity of the South Wales Coal-field which it traverses. Its total length is but 86 miles, 28 miles of which are single lines, the remaining 58 being double. In the 86 miles above referred to is included those other lines leased or worked by the Taff Vale Company, which are as follows:—The Aberdare, Cowbridge, Dare Valley, Llantrissant and Taff Vale Junction, Penarth Extension, Penarth Harbour Dock and Railway, and the Rhondda Valley and Hirwain Junction Railways. The extent of the traffic of coal and coke will be seen in the annexed table for the four decennial periods ending 1880:—

Railway Distribution.	1850.	1860.	1870.	1880.
	Tons.	Tons.	Tons.	Tons.
To Cardiff and Penarth Junction	564,698	1,929,525	3,415,193	5,955,457
Sold retail	29,524	203,470	363,226	356,691
To Quaker's Yard Junction	..	..	81,050	135,419
To Mountain Ash Junction	..	..	6,685	4,006
Conveyed over by other railways	..	..	77,507	345,757
To Brecon and Merthyr Junction	..	..	..	97,010
To Walnut Tree Bridge Junction	..	..	..	63
Totals	594,222	2,132,995	3,943,661	6,894,403

No. 7. The Coal Consumed in the Metropolis, amounting to upwards of 13 per cent. of the total produce of Great Britain during the year 1880, was conveyed to London in the following proportions by sea, railway and canal in 1880 and previous years since 1823: that brought by sea being the produce of the Durham and Northumberland Coal-field:—

COAL BROUGHT INTO LONDON BY SEA, CANAL, AND RAILWAY SINCE THE YEAR 1823.

Year.	Sea.	Canal.	Railway.	Total.
	Tons.	Tons.	Tons.	Tons.
1823	1,574,412	993	...	1,575,405
1824	1,828,177	1,695	...	1,829,872
1825	1,870,349	1,658	...	1,872,007
1826	1,813,757	1,686	...	1,815,443
1827	1,985,969	2,149	...	1,988,118
1828	1,960,559	547	...	1,961,106
1829	2,018,975	...	...	2,018,975
1830	2,079,275	...	...	2,079,275
1831	2,045,292	10,742	...	2,056,034
1832	2,139,078	6,905	...	2,145,983
1833	2,010,409	4,395	...	2,014,804

COAL BROUGHT INTO LONDON SINCE 1823—*continued.*

Year.	Sea.	Canal.	Railway.	Total.
	Tons.	Tons.	Tons.	Tons.
1834	2,078,635	1,862	...	2,080,497
1835	2,298,812	1,004	...	2,299,816
1836	2,402,474	1,199	...	2,403,673
1837	2,543,742	2,324	...	2,546,066
1838	2,518,085	1,686	...	2,519,771
1839	2,625,323	12,933	...	2,638,256
1840	2,566,899	22,188	...	2,589,087
1841	2,909,144	33,594	...	2,942,738
1842	2,723,200	31,519	...	2,754,719
1843	2,628,520	34,593	...	2,663,113
1844	2,490,910	72,275	...	2,563,165
1845	3,392,512	60,310	8,377	3,461,199
1846	2,920,376	21,872	11,698	2,953,946
1847	3,280,420	22,005	19,336	3,321,761
1848	3,418,340	19,918	37,888	3,476,138
1849	3,339,146	19,222	19,639	3,378,007
1850	3,553,304	29,479	55,095	3,637,878
1851	3,236,542	29,434	247,908	3,507,884
1852	3,330,428	33,913	377,907	3,742,248
1853	3,373,256	21,644	629,712	4,014,612
1854	3,399,561	32,153	945,056	4,376,770
1855	3,016,869	23,250	1,137,835	4,177,954
1856	3,119,884	25,401	1,246,299	4,391,584
1857	3,133,459	26,295	1,206,775	4,366,529
1858	3,266,446	20,244	1,190,521	4,477,191
1859	3,299,170	16,964	1,191,169	4,507,303
1860	3,573,377	19,593	1,477,545	5,070,515
1861	3,567,002	18,217	1,642,502	5,227,721
1862	3,442,402	11,651	1,513,296	4,967,349
1863	3,335,174	9,226	1,775,487	5,119,887
1864	3,116,703	8,902	2,342,440	5,468,045
1865	3,161,683	8,532	2,733,056	5,903,271
1866	3,033,193	10,176	2,969,896	6,013,265
1867	3,016,416	9,965	3,295,652	6,322,033
1868	2,918,230	9,527	2,979,333	5,907,090
1869	2,873,688	6,941	3,341,585	6,222,214
1870	2,993,710	7,301	3,758,089	6,759,100
1871	2,762,712	6,615	4,449,141	7,218,468
1872	3,548,918	8,236	4,999,268	7,556,422
1873	2,665,680	11,195	5,147,413	7,824,288
1874	2,727,719	5,982	4,689,785	7,423,486
1875	3,134,846	4,594	5,065,452	8,204,892
1876	3,273,442	4,696	5,173,297	8,451,375
1877	3,170,601	4,608	5,416,474	8,591,683
1878	3,198,309	2,977	5,593,290	8,794,576
1879	3,508,526	2,910	6,547,375	10,058,811
1880	3,714,708	4,470	6,196,310	9,915,488

The earliest account met with of coal brought to London by railway is for the year 1845, when 8,377 tons were conveyed into the Metropolis, increased in 1880 to 6,196,310 tons. The

annexed returns for the years 1860, 1870, and 1880, give the quantities carried by the several railway companies into London, to which are also appended the quantities brought by sea, and the ports from which received, in each of the said years: *—

By Railway and Canal.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
London and North-Western Railway .	693,419	835,281	1,436,338
Great Northern Railway	502,813	978,049	949,740
Great Western Railway	63,944	470,853	1,055,609
Great Eastern Railway .	121,226	507,344	669,288
Midland Railway . .	58,490	923,660	1,999,668
London and South-Western Railway	17,589	27,560	59,369
South-Eastern Railway.	14,585	10,482	20,196
London, Chatham, and Dover Railway .	104	4,572	6,007
London, Tilbury, and Southend . .	958	262	94
Total . . .	1,477,545†	3,758,089‡	6,196,309
Canals . .	19,593	7,301	4,471
Total . . .	1,497,138	3,765,390	6,200,780
By Sea.			
Newcastle . . .	1,347,574	1,507,078	2,005,064
Seaham	210,418	107,798	225,914
Sunderland . . .	977,519	769,243	948,151
Middlesbro' . . .	61,183	72,830	17,809
Hartlepool and West Hartlepool .	703,836	409,754	286,294
Blyth	40,986	3,562	200
Scotland . . .	13,002	39,902	63,379
Wales	130,009	25,937	94,638
Yorkshire . . .	45,230	40,966	22,632
Duff	...	...	230
Small Coal . .	25,047	8,432	41,956
Culm	1,902	444	...
Cinders . . .	16,671	6,962	6,070
Colonial . . .	...	...	2,350
Total. . .	3,573,377	2,993,710§	3,714,708‖
Total by Rail, Canal, and Sea . .	5,070,515	6,759,100	9,915,488

* From Mr. James R. Scott's "Coal and Coke Returns" published by the authority of the Corporation of London.

† Including 4417 tons carried by the Hereford and Luton Railway.

‡ Including 26 tons carried by the London and Brighton Railway.

§ Including 802 tons from Lancashire.

‖ Including 21 tons of foreign coal.

No. 8, Coals, Cinders and Culm.—An account of the quantities shipped at the several ports of England, Scotland, and Ireland, coastways, since the year 1834, to other ports of the United Kingdom (from Parliamentary Returns) :—

Year.	England.	Scotland.	Ireland.	Total.
	Tons.	Tons.	Tons.	Tons.
1834	5,280,632	538,771	3,158	5,822,561
1835	5,558,345	557,043	2,605	6,117,993
1836	5,921,245	548,076	3,083	6,472,404
1837	6,538,906	547,680	4,105	7,090,691
1838	6,572,635	613,875	3,923	7,190,433
1839	6,521,577	699,348	2,088	7,223,013
1840	6,749,690	723,534	2,653	7,475,877
1841	7,020,289	627,060	2,550	7,649,899
1842	7,079,588	567,036	2,845	7,649,469
1843	6,906,316	539,156	1,612	7,447,084
1844	6,731,647	644,388	1,827	7,377,862
1845	8,191,772	530,388	1,308	8,723,468
1846	7,838,668	465,173	1,601	8,305,442
1847	8,442,567	431,308	724	8,874,599
1848	8,576,148	496,816	1,115	9,074,079
1849	8,082,200	469,918	588	8,552,706
1850	8,901,885	463,123	2,770	9,367,778
1851	8,319,956	496,106	476	8,816,538
1852	8,567,985	501,413	179	9,069,577
1853	8,594,063	476,767	154	9,070,984
1854	8,796,135	476,772	258	9,273,165
1855	8,322,403	530,578	161	8,853,142
1856	8,570,489	539,407	180	9,110,076
1857	8,934,906	598,569	201	9,533,676
1858	8,960,026	565,704	81	9,525,811
1859	9,536,913	570,790	130	10,107,833
1860	9,977,397	743,214	105	10,720,716
1861	10,266,228	726,249	120	10,992,597
1862	10,016,420	857,786	70	10,874,276
1863	9,634,888	753,244	120	10,388,252
1864	10,099,834	870,877	...	10,970,711
1865	10,064,966	863,291	...	10,928,257
1866	9,901,675	819,029	120	10,720,824
1867	10,295,042	1,004,348	...	11,299,390
1868	9,652,234	923,001	40	10,575,275
1869	9,534,957	917,178	...	10,452,135
1870	10,042,973	1,062,693	...	11,105,666
1871	9,615,760	1,115,558	...	10,731,318
1872	8,965,457	1,171,340	...	10,136,797
1873	9,143,820	1,324,985	...	10,468,805
1874	8,502,257	1,079,792	...	9,582,049
1875	9,301,352	1,408,515	...	10,709,867
1876	9,692,397	1,307,296	...	10,999,693
1877	9,686,801	1,278,703	80	10,965,504
1878	8,732,399	1,325,698	...	10,058,097
1879	10,623,380	1,421,743	330	12,045,453
1880	10,602,908	1,215,816	70	11,818,794

No. 9. Coal Exported to Foreign Countries.—From a Parliamentary paper published in the year 1831,* it appears that the total quantity of coals, cinders, and culm exported to foreign countries amounted to 237,657 tons; of this quantity 217,681 tons were conveyed in British ships, and 19,976 tons in the ships of foreign nations. In subsequent years, till 1829, the following quantities were annually sent out of the country, with the amount of duty paid thereon:—

Year.	In British Shipping.				In Foreign Shipping.			
	Quantity.	Duty.			Quantity.	Duty.		
	Tons.	£	s.	d.	Tons.	£	s.	d.
1816	217,681	61,253	3	0	19,976	7,286	17	7
1817	220,811	50,262	16	5	32,330	10,301	15	11
1818	221,703	43,103	11	0	50,753	16,556	8	4
1819	202,156	37,654	1	6	36,084	11,208	6	5
1820	221,080	39,970	17	2	29,860	8,388	6	7
1821	236,085	43,506	4	9	26,884	7,405	8	4
1822	251,702	42,775	5	7	35,694	9,996	10	10
1823	217,256	34,550	14	8	36,741	9,470	0	1
1824	221,484	29,584	5	4	60,531	13,238	6	3
1825	235,298	29,774	5	5	77,948	13,646	16	4
1826	278,588	28,849	18	3	69,693	11,703	19	5
1827	288,071	30,008	13	4	80,608	15,173	15	11
1828	294,727	30,239	4	0	63,137	11,190	8	2
1829	283,574	29,143	4	1	87,696	14,739	11	11

The quantities of coals, cinders, and culm exported from the United Kingdom in the three years ending 1832, with the amount of duties received thereon, were as follows: †—

Year.	Quantities.	Value.		
	Tons.	£	s.	d.
1830	504,419	63,889	17	6
1831	510,831	55,237	5	10
1832	588,446	56,706	2	10

The duty levied on coals at this period to foreign countries was 3*s.* 4*d.* per ton in British ships, and 6*s.* 8*d.* per ton in other ships; small coals, cinders, and culm paying 2*s.* per ton in British ships, and 4*s.* per ton in other ships. In the year 1833 the total

* No. 287. "Account of the quantities of Coal exported to Foreign Countries." House of Commons paper, printed 25th March, 1831.

† *Ibid.*, No. 586. 29th July, 1833.

exports of coals, cinders, and culm amounted to 634,448 tons, the duty paid on the same amounting to £65,008 8*s*. 6*d*. The particulars are as follows:—

Description.	Quantities.	Duty.		
	Tons.	£	*s.*	*d.*
Coals	409,665	41,677	1	0
Small coals . . .	223,819	23,296	19	6
Culm	964	34	8	0
Total . . .	634,448	65,008	8	6

Between the years 1833 and 1850, in which latter year the duty on coal exported to foreign countries and British settlements was wholly repealed, the exports were as follows:—

Year.	Coals.	Cinders.	Culm.	Total.
	Tons.	Tons.	Tons.	Tons.
1834	609,756	3,654	1,845	615,255
1835	729,478	3,964	2,618	736,060
1836	910,773	5,191	904	916,868
1837	1,106,020	6,447	1,143	1,113,610
1838	1,303,384	9,693	632	1,313,709
1839	1,431,861	17,163	393	1,449,417
1840	1,592,283	13,783	247	1,606,313
1841	1,831,554	16,514	226	1,848,294
1842	1,975,280	23,434	790	1,999,504
1843	1,820,284	42,698	3,229	1,866,211
1844	1,698,391	49,389	6,391	1,754,171
1845	2,442,740	84,556	3,986	2,531,282
1846	2,432,382	95,554	3,172	2,531,108
1847	2,390,087	88,884	4,190	2,483,161
1848	2,699,468	82,908	2,924	2,785,300
1849	2,730,567	95,630	1,842	2,828,039
1850	3,211,619	137,348	2,913	3,351,880

Since the abolition of the duties on coal and cinders* in 1850, a greatly increased demand for British coal has arisen, the exports increasing from 3,351,880 tons in 1850 to 18,702,551 tons in 1880, showing an increase of upwards of 500 per cent. in a period of thirty years. In the annexed statement is given the total quantities exported, of coal, cinders, and culm, its declared value at the port of shipment, and the average value per ton in each year since 1850:—

* The duty was wholly repealed by Act 13 & 14 Vict. c. 95. From 14th August, 1850.

Year.	Quantities.	Value.	Price per Ton.
	Tons.	£	s. d.
1850	3,351,880	1,284,224	7 8
1851	3,468,545	1,302,473	7 6
1852	3,640,194	1,372,114	7 6
1853	3,935,062	1,604,591	8 2
1854*	3,359,575	2,164,405	10 0
1855	5,061,762	2,505,326	9 9
1856	5,949,241	2,869,230	9 7
1857	6,821,750	3,264,098	9 7
1858	6,597,128	3,088,747	9 3
1859	7,082,029	3,315,279	9 4
1860	7,412,575	3,371,631	9 1
1861	7,934,832	3,652,164	9 2
1862	8,380,673	3,798,727	9 1
1863	8,342,500	3,752,308	9 0
1864	8,900,872	4,220,883	9 6
1865	9,283,214	4,496,567	9 8
1866	10,142,260	5,218,498	10 1
1867	10,565,829	5,488,945	10 5
1868	10,967,062	5,487,922	9 11
1869	10,744,945	5,165,668	9 7
1870	11,702,649	5,638,371	9 8
1871	12,747,989	6,246,133	9 11
1872	13,198,494	10,442,821	16 10
1873	12,617,566	13,188,551	20 11
1874	13,927,205	11,984,621	17 3
1875	14,544,916	9,658,088	13 3
1876	16,265,839	8,901,716	10 11
1877	15,420,050	7,844,486	10 2
1878	15,483,816	7,321,424	9 5
1879	16,442,296	7,206,799	8 10
1880	18,702,551	8,378,944	8 11

Considerable quantities of coal are annually shipped from the ports of Great Britain for the use of steamers engaged in the foreign trade. The shipments for the year 1874 were 3,140,383 tons. Since that date the quantities are as follows:—

Year.	Tons.	Year.	Tons.
1875	3,278,249	1878	4,018,010
1876	3,564,524	1879	4,401,120
1877	3,661,552	1880	4,926,076

Coal, Coke, Cinders and Manufactured Fuel exported from Great Britain, and the countries to which exported, in each of the years 1860, 1870, and 1880: †—

* Patent fuel not included between the years 1854 and 1860.

† According to "Trade and Navigation Returns." Manufactured fuel exported is included in the returns for 1880.

Countries to which Exported.	1860.	1870.	1880.
	Tons.	Tons.	Tons.
Russia	356,147	829,514	1,498,426
Denmark	418,163	695,704	860,373
Sweden	...	385,763	1,317,274
Prussia	399,174	547,541	...
Hanse Towns	539,477	800,240	...
Holland	316,768	412,833	498,049
France	1,393,330	2,082,224	3,711,720
Spain and Canaries	452,436	584,310	895,239
Turkey	196,119	...	289,152
United States	309,870	106,494	...
Italy (Sardinia)	...	387,165	1,531,009
Brazil	...	271,573	359,193
British India	...	426,575	854,784
Germany	...	...	2,239,947
Egypt	...	...	649,846
Malta	...	...	388,057
Other Countries	2,966,844	3,965,156	3,609,482
Total	7,348,328	11,495,092	18,702,551
Declared Value	£3,321,539	£5,506,890	£8,378,944

No. 10. Patent Fuel Exported from Great Britain to foreign countries, with the declared value at port of shipment, and average value per ton. In the year 1854 the quantities exported amounted to 50,320 tons, of the value of £37,249, giving an average value of 14*s.* 10*d.* per ton. Since that date the returns are as follows:*—

Year.	Quantities.	Value.	Average price per Ton.	Year.	Quantities.	Value.	Average price per Ton.
	Tons.	£	*s.* *d.*		Tons.	£	*s.* *d.*
1855	84,860	58,985	13 10	1868	129,258	85,397	13 2
1856	69,462	42,648	12 4	1869	156,520	97,878	12 6
1857	84,032	53,437	12 8	1870	198,377	123,742	12 0
1858	67,645	43,313	12 2	1871	198,115	125,034	12 1
1859	75,080	45,266	12 0	1872	207,241	189,335	18 3
1860	90,743	55,350	12 2	1873	278,410	317,878	22 10
1861	79,717	47,374	11 10	1874	309,894	310,917	20 0
1862	78,821	47,860	12 2	1875	253,331	203,681	16 1
1863	67,288	38,510	11 5	1876	231,968	164,738	14 2
1864	90,964	55,110	12 1	1877	205,511	114,313	11 1
1865	112,737	69,390	12 3	1878	221,867	118,730	10 8
1866	188,548	115,693	12 3	1879	356,776	181,196	10 2
1867	150,051	96,493	12 10	1880	385,993	197,360	10 3

* "Trade and Navigation Returns."

Population Employed in Coal-mining in the United Kingdom.—All the early returns on this subject were careful estimates made by the Inspectors, each in his own district. Since 1872, when the "Coal Mines Regulation Act" came into operation, very complete returns have been published in the annual reports of H.M. Inspectors of Mines, in which the numbers engaged under and above ground are separately distinguished, together with the quantity of coal raised, which appear in the annexed table, to which is added the average production per man in each year:—

Year.	Persons Employed.		Total.	Coal Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	407,808	106,341	514,149	128,680,131	250
1874	428,611	110,218	538,829	126,590,108	235
1875	427,017	108,828	535,845	133,306,485	245
1876	409,229	105,303	514,532	134,125,166	266
1877	395,025	99,366	494,391	134,179,968	278
1878	382,979	92,350	475,329	132,612,063	279
1879	385,179	91,631	476,810	133,720,393	280
1880	391,381	93,552	484,933	146,969,409	303

These figures indicate the increased efficiency of the coal-miner in recent years. When, in 1873, the year of the Coal Famine, the average output per man was 250 tons per annum, a less number of persons were employed than in the succeeding year when the average fell to 235 tons per man, the diminished production being due to the larger amount of unskilled labour employed. Since 1874, however, the efficiency of the coal-miner has gone on increasing, till, in 1879, the average amounted to 280 tons, and in 1880 to 303 tons per annum.

Of the population employed in coal-mining, the annexed abstract will show the numbers and respective ages of all engaged under and above ground in the collieries of the United Kingdom in the year 1873, when the first return appeared, and for the years 1879 and 1880; the last-named year showing an increase of 8,123 persons employed in excess of the previous year, and an increase of 23 tons per man:—

Ages.	1873. Persons Employed.	1879. Persons Employed.	1880. Persons Employed.
	Nos.	Nos.	Nos.
Under Ground—			
From 10 to 12 . .	1,202	446	428
„ 12 to 13 . .	11,309	4,881	4,868
„ 13 to 16 . .	45,931	35,993	36,162
Above 16 . . .	349,366	343,859	349,923
Above Ground—			
Males, 10 to 13 . .	2,070	671	552
Females, 10 to 13 .	31	9	10
Males, 13 to 16 . .	6,957	6,572	7,037
Females, 13 to 16 .	790	502	354
Males, above 16 . .	91,110	79,546	81,323
Females, above 16 .	5,383	4,331	4,276
Total . . .	514,149	476,810	484,933

Resources and Probable Duration of the Coal-fields of the United Kingdom.—The total quantity of coal ascertained by the Royal Coal Commission as available for future use, amounts, in the aggregate, to 146,180,285,398 tons. Of this quantity 90,207,285,398 tons exist at depths not exceeding 4,000 feet in known coal-fields, and 56,273,000,000 tons as the probable amount of coal, under Permian and other overlying formations, at depths of less than 4,000 feet; 40 per cent. being deducted for loss and other contingencies. The details of quantities under the first head, visible coal-fields, appear in the annexed table from the Coal Commission Report.* Side by side are given the quantities of coal remaining and available for future use from 1880, amounting to 79,015,613,038 tons, divided as follows in the visible coal-fields of the United Kingdom:—

	TONS.
England and Wales	69,192,056,317
Scotland	9,669,172,642
Ireland	154,384,079
Total known coal-fields	79,015,613,038
Concealed coal-fields	56,273,000,000
Total coal available, 1880 . . .	135,288,613,038

With these available resources, and an annual output of nearly 147 millions of tons, supplies are yet ensured for 920 years hence.

* Vol. I., p. 9. C. 435. 1871.

Commission.	No.	Name of Coal-field.	Amount of Coal in statute tons, to depths not exceeding 4000 feet, and after the necessary deductions.	Amount of Coal remaining and available for future use from the year 1880.
			Tons.	Tons.
		ENGLAND AND WALES.		
Messrs. Vivian and Clark	1	South Wales	32,456,208,913	32,302,046,783
Mr. Dickinson . . .	2	Forest of Dean . . .	265,000,000	257,623,705
Mr. Prestwich . . .	3	Bristol	4,218,970,762	4,207,076,209
Mr. Woodhouse . .	4	Warwickshire . . .	458,652,714	450,179,258
Mr. Hartley . . .	5	South Staffordshire .		
"	6	Coalbrookdale and Forest of Wyre	1,906,119,768	1,789,674,298
"	7	Clee Hills		
Mr. Woodhouse . .	8	Leicestershire . . .	836,799,734	826,799,734
Mr. Dickinson . . .	9	North Wales	2,005,000,000	1,986,229,493
"	10	Anglesea	5,000,000	
Mr. Elliot	11	North Staffordshire . .	3,825,488,105	3,784,377,741
Mr. Dickinson . .	12	Lancashire and Cheshire	5,546,000,000	5,270,686,699 192,104,295
Mr. Woodhouse . . .	13	Midland	18,172,071,433	17,928,908,710
"	14	Black Burton . . .	70,964,011	70,964,011
Messrs. Forster and Elliot	15	Durham and Northumberland	10,036,660,236	9,734,261,887
"	16	Cumberland	405,203,792	391,123,499
		SCOTLAND.		
Mr. Geddes	17	Edinburgh	2,153,703,360	
"	18	Lanarkshire	2,044,090,216	
"	19	Fifeshire	1,098,402,895	
"	20	Ayrshire	1,785,397,089	
"	21	East Lothian . . .	86,849,880	
"	22	Frith of Forth . . .	1,800,000,000	
"	23	Dumfriesshire	358,173,995	
"	24	West Lothian	127,621,800	9,669,172,642
"	25	Perthshire	109,895,040	
"	26	Stirlingshire	106,475,436	
"	27	Clackmannanshire . . .	87,563,494	
"	28	Dumbartonshire . . .	48,618,320	
"	29	Renfrewshire	25,881,285	
"	30	Argyleshire	7,223,120	
"	31	Sutherlandshire	3,500,000	
"	32	Roxburghshire . . .	70,000	
		IRELAND.		
Professor Jukes * and Professor Hull . .	33	Ballycastle (Antrim Co.) .	16,000,000	
" " .	34	Tyrone	6,300,000	
" " . .	35	Leinster (Queen's Co.) . .	77,580,000	154,384,079
" " .	36	Tipperary	25,000,000	
" " . .	37	Munster (Clare, &c.) . .	20,000,000	
" " .	38	Connaught	10,800,000	
		Total .	90,207,285,398	79,015,613,038

The details of coal remaining unwrought, as estimated by Professor Ramsay, and contained under the second head,

* The estimate of the quantity of coal in Ireland, commenced by Professor J. B. Jukes, F.R.S., was on the decease of that gentleman completed by Professor E. Hull, F.R.S., author of "The Coal Fields of Great Britain."

under Permian and other overlying formations, amounting to 56,273,000,000 tons, is as follows: *—

Districts.	Under.	Square Miles.	Tons.
Warwickshire	Permian	73	2,165,000,000
Warwickshire, south of Kingsbury	New Red	5	150,000,000
Warwickshire, north of Atherstone	,,	6	179,000,000
Leicestershire, Moria District	Permian	15	1,000,000,000
Leicestershire, Coleorton District	New Red	25 to 28	790,000,000
District between the Warwickshire and South Staffordshire Coal-field	Permian and New Red	116	3,400,000,000
District between South Staffordshire and Shropshire Coal-fields	,,	195	5,800,000,000
Between the South Staffordshire and Coalbrookdale Coal-fields, to the Cheadle and North Staffordshire Coal-fields	,,	200	4,580,000,000
East of the Denbighshire Coal-field	,,	50	2,489,000,000
West and South-West Border of the North Staffordshire Coal-field	,,	50	1,500,000,000
Cheshire, West of the Kerridge	,,	9	62,000,000
Cheshire, between Woodford Fault and Denton	,,	36	1,790,000,000
Lancashire, East and West of Manchester	,,	30	350,000,000
Lancashire, West of Eccles and Stretford, to Prescott, Runcorn, and Hale-on-the-Mersey	,,	130	3,883,000,000
The Wirrell, the Mersey, and country to the North	New Red	216	3,000,000,000
Yorkshire, Derbyshire, and Nottinghamshire	Permian and New Red	900	23,082,000,000
Vale of Eden	,,	40	1,593,000,000
Ingleton and Burton	,,	3	33,000,000
Severn Valley	New Red Marl	45	400,000,000
Scotland	Permian	†	†
Ireland, Tyrone	New Red Marl	4	27,000,000
Total of concealed coal-fields			56,273,000,000

* "Coal Commission Report," Vol. I., p. xi.

† No estimate.

THE

COAL AND IRON INDUSTRIES

OF

THE UNITED KINGDOM.

PART II.

IRON INDUSTRIES.

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IRON INDUSTRIES.

INTRODUCTORY CHAPTER.

THE MINERALOGICAL CHARACTERS OF THE PRINCIPAL IRON ORES.

BY FRANK RUTLEY, ESQ., F.G.S.

THE principal ores of iron are oxides and carbonates, which frequently contain various impurities; the carbonates especially being often rendered impure by a large admixture of argillaceous matter.

Pure metallic iron is very seldom found, except in meteorites, and must be regarded as a mineralogical rarity.

Arsenic is derived from mispickel, the bisulphide and arsenide of iron, and sulphur is sometimes procured from pyrites, although native sulphur is the principal source of supply. Alum is also manufactured from pyritous shales, the pyrites by its decomposition and oxidation giving rise to sulphuric acid, which acts upon the shales and, with the addition of potash compounds, results in the formation of hydrous sulphate of alumina and potash.

The following ores, which are useful to the iron-smelter, are here briefly described:—

Oxides.

Magnetite, Hematite, Limonite, Göthite.

Carbonates.

Spathose Iron Ore or Chalybite, Clay Ironstones.

Magnetite (Fe_3O_4).—Approximate composition, Peroxide of Iron = 69, Protoxide of Iron = 31. The iron is sometimes partly replaced by a little magnesium or titanium. It crystallizes in the cubic system, commonly in the form of the octahedron or of

the rhombic dodecahedron. The cleavage is parallel to faces of the octahedron. It is also found in granular and massive conditions, and occasionally in the form of sand, in which case it is readily separated from foreign admixtures by means of magnets.

Magnetite is iron-black in colour and opaque. Its lustre is metallic or sub-metallic. The streak is black; the fracture sub-conchoidal; the hardness, 5·5 to 6·5 of Moh's scale, and the specific gravity, 4·9 to 5·2. It is strongly magnetic, and frequently shows polarity, but loses its magnetic properties when heated in the oxidising flame of the blow-pipe.

Magnetite is very difficultly fusible before the blow-pipe. With borax, in the oxidising flame, the bead is yellow when hot and colourless when cold. The addition of considerably more of the powdered mineral renders the bead red when hot and yellow when cold. In the reducing flame the bead becomes green (the colour of ordinary bottle glass).

Magnetite is soluble in hydrochloric acid. It becomes reduced by the action of organic matter to the condition of protoxide, which may be converted into the carbonate (Chalybite or Siderite). Further oxidation of magnetite results in the formation of hematite, the sesquioxide, which, in its hydrated condition, constitutes limonite.

Hematite, Sesquioxide of Iron (Fe_2O_3). Oxygen = 30, Iron = 70 per cent.—Titanium and magnesium sometimes replace part of the iron. Hematite occurs in massive, granular, columnar, stalactitic, reniform ("*Kidney ore*"), micaceous and earthy (*Reddle*) conditions. It also occurs crystallised (*Specular iron*) in the rhombohedral system, commonly in modified rhombohedrons. The cleavage is parallel to faces of the rhombohedron and to the basal plane, but is frequently indistinct. Hematite is, under ordinary conditions, opaque and dark steel-grey or iron-black, but in very thin scales or crystals it appears blood-red to orange-red by transmitted light. This may be well seen in the microscopic crystals which occur so plentifully in the Carnallite of Stassfurth. The fracture is sub-conchoidal or uneven, and the streak is cherry-red. The lustre is metallic and sometimes splendent, as in the specular varieties; but the impure and ochreous conditions have a dull or earthy appearance. The hardness ranges from 5·5 to 6·5, and the specific gravity from 4·2 to 5·3.

It is sometimes attractable by the magnet and at times shows magnetic polarity. Hematite occasionally contains a considerable admixture of argillaceous or siliceous impurities.

Before the blow-pipe it is infusible. When heated on charcoal in the reducing flame it becomes magnetic. In the borax bead it behaves like magnetite. It is soluble in strong hydrochloric acid.

Limonite.—Hydrous Sesquioxide of Iron, having the formula $2\ Fe_2O_3,\ 3\ H_2O$.—It occurs in stalactitic and mammillated forms with a radiating fibrous structure like that of the reniform varieties of hematite. It is usually of a brown colour, sometimes yellowish-brown, and has a rather dull sub-metallic or silky lustre, often with a shiny black coating. It is also met with in an earthy and porous condition, called bog-iron-ore or morass-ore, from its occurrence in swamps, and it is occasionally pisolitic in structure (pea-iron-ore). The earthy varieties also constitute brown and yellow ochres, which are employed as pigments. Impure argillaceous varieties are known as clay-ironstone, a name also used to designate the impure argillaceous varieties of chalybite, siderite or spathose iron.

Limonite may be distinguished from hematite by giving a yellowish-brown streak. The hardness of limonite is 5 to 5·5, and the specific gravity 3·6 to 4. It affords the usual iron reactions before the blow-pipe, and yields water when heated. Limonite is often associated with manganese ores.

Göthite.—Hydrous Sesquioxide of Iron, having the formula $Fe_2O_3,\ H_2O_3$.—It frequently contains some silica and manganese, and occasionally traces of phosphorus. The water usually amounts to about 10 or 11 per cent. It crystallizes in the rhombic system, generally in right rhombic prisms longitudinally striated and often tabular in form. It is likewise met with in fibrous, reniform, stalactitic, and earthy conditions. It is blackish-brown, yellowish or reddish in colour. The streak is brownish yellow, and the lustre adamantine. Göthite has a hardness of 5 to 5·5, and its specific gravity ranges from 4 to 4·4. It is often associated with limonite and hematite. Heated in the closed tube göthite gives off water and is converted into red sesquioxide. With the fluxes it affords the usual iron, and sometimes the manganese reaction. It is soluble in hydrochloric acid.

Franklinite.—A Sesquioxide of Iron and Manganese, with over 11 per cent. of oxide of zinc, is an important iron ore in America, but has not been met with in Great Britain.

Spathose Iron Ore (Chalybite, Siderite).—Carbonate of Iron ($Fe\ CO_3$).—Often with a little lime, magnesia and manganese. Crystallizes in the rhombohedral system, the common form being the rhombohedon, the faces of which often show a well-marked curvature, similar to that seen in crystals of pearlspar and dolomite, in which minerals the isomorphous substances, lime and magnesia, take the place of the peroxide of iron. Spathose iron ore also occurs in massive and crystalline-granular conditions, as in the ore from the Brendon Hills and Tintagel. Its colour is pale brown or yellowish, sometimes brownish-red and brownish-black. It is generally opaque, but occasionally crystals are translucent. It is brittle and the fracture is uneven, but it often breaks up along well-marked cleavage planes, which coincide with the faces of the rhombohedron. The lustre is pearly, sometimes vitreous. The hardness is 3·5 to 4·5, and the specific gravity, 3·7 to 3·9. Before the blow-pipe, alone, it blackens and becomes magnetic, and with the fluxes affords the usual iron reactions. In hot acids it effervesces rapidly, but is only slowly affected by them in the cold.

Clay Ironstone is an impure massive variety of the preceding mineral and, as its name implies, contains a considerable admixture of argillaceous matter. In the coal measures it occurs in bands, usually of a dark brownish or blackish colour, containing carbonaceous matter, and known as "black band," and also in nodules of spherical or lenticular form; frequently with rusty surfaces, and with a concentrically-zoned structure; while, at times, a curious structure, known as "cone in cone," is developed, in which case the block, when broken, reveals more or less regular cones lying side by side, their apices directed towards the same point and their surfaces marked by irregular transverse corrugations, and these cones contain other smaller ones, which may easily be detached or picked out when loosened by a blow. The clay ironstone of the Middle Lias commonly shows a fine oolitic structure, and in the Cleveland district constitutes a valuable ore, which, however, sometimes contains siliceous impurities. The pisolitic iron ore of Rosedale in Yorkshire consists in great part of carbonate of iron, but also contains a considerable amount of the magnetic oxide.

The titaniferous iron ores, although worked in other countries do not occur in the British Isles in sufficiently large deposits to

render them a matter of commercial interest. Titaniferous iron is of frequent occurrence as a constituent of many of our eruptive rocks, but it is disseminated through them in such minute crystals and grains that it needs no further mention in this work, and the same may be said of the microscopic crystals of magnetite which occur under similar conditions.

CHAPTER I.

DURHAM AND NORTHUMBERLAND IRON INDUSTRIES.

Ironstone of the Coal measures and analyses—Iron-ores of the Carboniferous Limestone and analyses—Production of Iron ore—Population employed in Iron Mining—Pig iron manufacture, early history—Production of Durham and Northumberland—Malleable Iron Works—Coal and Iron Ore used in Pig iron manufacture—Quantities of Iron ore employed and Sources of Supply.

Ironstone of the Coal Measures and Analyses.—The coal measures yield two kinds of ironstone known as "Clay Band" and "Black Band," the former is an argillaceous carbonate of iron generally occurring in nodular masses; the latter term is applied to bands of carbonaceous matter, largely mixed with carbonate of iron. Formerly, the first-named variety furnished nine-tenths of the iron produced in Great Britain; it does not, however, exist abundantly in the Great Northern, or Lancashire and Cumberland coal-fields. At present the Clay Bands and Black Bands furnish one-fourth of the annual produce of the pig-iron of the kingdom. The coal-fields in which they are extensively worked being Shropshire, Derbyshire, Yorkshire, North and South Staffordshire, South Wales, and Scotland, the ironstone being found in irregular nodules, interspersed through the clays and shales of the coal measures, and being often worked in conjunction with coal seams in the same pits.

Ironstone has been worked from time to time, though in inconsiderable quantities, in the Wear district; occurring in a continuous band above the seam of coal known as the High Main, and separated from it by a distance of 18 inches. This ironstone measure is 4½ inches thick, and was formerly worked on Waldridge Fell for the Whitehill ironworks, and subsequently at Urpeth and its vicinity for the blast furnaces at Birtley, long since dismantled. At Wylam, upwards of forty years since, ironstone of very fair quality was obtained, yielding from 35 to 37 per cent of metallic iron, and at that time said to

cost 11*s.* 6*d.* per ton. This measure has a thickness of 10½ inches, contained in four bands occurring in a section of four feet. Another measure is stated to have cost 7*s.* 6*d.* per ton for working; the ironstone yielding an average of 30 per cent. of metallic iron.

At Shotley Bridge, again, on the western edge of the coal-field, and consequently low down in the series, is a deposit of ironstone which has been far more extensively worked than any other seams found in the coal measures. According to a description given by the late Mr. William Cargill, in a working having a section of about 7 feet in height, from 12 to 15 inches of stone were obtained from six or seven bands, the ironstone costing from 7 to 8 shillings per ton. At a depth of 4½ fathoms below it and lying above 20 inches of coal, is a bed of shale about 3 feet thick, containing from 6 to 7 inches of ironstone. The total yield of these two seams contained in an acre of ground has been estimated at 5,324 tons. At Stiddle Moor, near Bellingham, and at Ridsdale, ironstone, in the carboniferous limestone series, as well as in a few other localities (as at Brinkburn and Rothbury), has been wrought in recent years. The quantities obtained are, however, unimportant, not exceeding 5,000 tons per annum. Clay ironstone in smaller quantities occur frequently in the shales of the carboniferous limestone series of Northumberland; and at numerous places over the western moorlands there are slag heaps showing the sites of ancient furnaces. These are of very ancient date, some of them being believed to be Roman, charcoal being the fuel with which the ore was smelted. In a general sense, as has been already stated, the argillaceous ironstone of the coal measures in the Great Northern Coal-field contributes in a very small degree at the present time to the requirements of the 74 blast furnaces built in Durham and Northumberland, many of which have a height exceeding 100 feet, and of immense capacity, producing annually, when in full work, from 15 to 16 thousand tons of pig-iron, and sometimes even more.

The measures of ironstone existing in this coal-field are few and limited in extent. One of the many advantages possessed by Great Britain in the manufacture of iron arises from the number and variety of argillaceous and black band ironstones, which alternate with the beds of coal in many of its coal-fields, and, in consequence of which, the same localities, and, in many

instances, the same mineral working, frequently furnish both the ore and the fuel required to smelt it. These conditions as regards clay ironstone in the Durham and Northumberland coal-field do not exist, inasmuch as in this coal-field these measures of ironstone are almost absent; the same may be said of Lancashire, while in the coal-fields of Scotland, Yorkshire, Derbyshire, North and South Staffordshire, North and South Wales, and Shropshire, the ironstone measures are numerous, and afford an abundant supply of ironstone.

The yield of ironstone varies according to the thickness and regularity of the beds, and the regularity with which the nodules of ironstone are disseminated.

The ironstone of Ridsdale, Hareshaw, and from Consett, near Shotley Bridge, in the coal measures, previously referred to, have been examined by Dr. Richardson, with the following results:—

Constituents.	Ridsdale.	Hareshaw.	Shotley Bridge.
Iron	34·86	36·51	36·68
Lime and magnesia . . .	9·00	11·90	4·65
Clay	14·00	7·15	15·05
Loss by heat	31·02	34·07	31·91

It would appear that the samples from which the above analyses were made, were perfectly clean and free from adhering shale, which will account for the difference of metal between the analyses and the actual yield in the furnace, which did not exceed 26 per cent.

Iron Ores of the Carboniferous Limestone, and Analyses.—In Alston Moor, many of the mineral veins traversing the limestone contain a considerable quantity of a hydrated peroxide of iron, as well as amorphous carbonate of iron. These ores were formerly worked to a limited extent at Nent Head by the Messrs. Bell Brothers, and smelted at their works at Wylam. The iron obtained from these, as well as from similar ores of the same district, was of excellent quality; but unfortunately the supplies were too uncertain and the working too costly. The ore in the veins themselves was at one time a tolerably pure carbonate, yielding, perhaps, 30 per cent. or more of iron, but it gradually passed into carbonate of lime from which it was with difficulty distinguished. In the lead-mining district of Allen-

heads, sparry iron ores occur, both in the regular lodes and in the flats which insinuate themselves from them laterally into the limestone. "Adjoining Weardale this character is still more pronounced, and in the neighbourhood of Stanhope Burn the veins are so 'ridered'—so charged with the ore—that at a spot where several of them occur in close proximity, and interlacing 'strings' additionally enrich the ground. The whole surface has been removed from a large area by the Weardale Iron Company, and the rock absolutely quarried away, a considerable amount of lead ore being separated during the operation." * The ores raised by the above-named company are smelted at the Tow Law Iron Works, near Darlington. The following table gives the production and value of the Spathose ore raised in the Weardale district since the year 1870, the average price during the past few years being estimated at 12*s*. per ton:—

Year.	Ore.	Value.
	Tons.	£
1870	100,332	25,083
1871	88,449	22,112
1872	97,953	36,730
1873	99,393	39,813
1874	85,491	51,388
1875	34,828	21,626
1876	24,202	14,521
1877	51,344	30,806
1878	35,619	21,371
1879	16,679	10,007
1880	41,357	24,814

The ore is wrought in open quarry workings as well as mined in underground levels, and includes in these quantities some siliceous hematite.

Analyses of these ores. In the Iron Ores of Great Britain † appears the following, giving the composition of the Weardale ore. The first, from "West Level," made by Mr. John Spiller, is thus described:—

"An altered Spathose ore, in which the greater part of the carbonate of iron has been converted into hydrated peroxide, which in many places still shows the structure of the original ore. The portions which are undecomposed occur in irregular nodular-like form, of a pale brownish-grey colour; these are surrounded

* "Iron Ores of Great Britain," Part I., p. 19. † Ibid, p. 55.

by a mass varying from crystalline to earthy, of which the colour is from a snuff-brown to a dark purplish-brown. The streak varies with the colour from yellowish to reddish-brown.

"A small quantity of fluor spar was attached to one side of the specimen, but was not included in the portion selected for analysis."

RESULTS TABULATED.

Peroxide of iron	49·50
Protoxide of iron	10·77
Protoxide of manganese	3·06
Alumina	0·43
Lime	5·68
Magnesia	1·20
Silica	0·29
Carbonic acid	14·49
Phosphoric acid	0·01
Suphuric acid	trace
Bisulphide of iron	0·03
Water hygroscopie	1·81
,, in combination	6·63
Organic matter	trace
Insoluble residue	6·90
	100·80

INSOLUBLE RESIDUE.

Silica	6·35
Alumina	0·41
Peroxide of iron	0·07
Lime	0·01
Magnesia	0·01
Potash	0·05
	6·90

The total amount of metallic iron contained in this ore amounts to 43·02 per cent. A trace of lead was found in 400 grains of the ore.

Another variety of Weardale ore from the Rispey vein near Rookhope is thus described by Mr. A. Dick:—"Spathose ore: easily scratched by the file; lustre, semi-vitreous; colour, yellowish grey; streak, white; fracture, crystalline. Some portions are much darker than others. When a mass of the ore is digested in hydrocholoric acid till all carbonates are dissolved, there remains a skeleton of quartz, having the shape and size of the original mass, containing casts of the crystals which have been dissolved. The dark-coloured parts of the ore leave a dark

skeleton, which, when exposed to the vapour of hydrofluoric acid till all silica is removed, leaves a small amount of matter, having a dark grey colour. When this is washed with hydrochloric acid and water, there remains a very small amount of black matter, which burns when heated in the air, and leaves no residue. It is therefore carbonaceous matter."

RESULTS TABULATED—ORE DRIED ABOVE 100° C.

Protoxide of iron	49·47
Protoxide of manganese	2·42
Alumina	trace
Lime	3·47
Magnesia	3·15
Carbonic acid	37·71
Phosphoric acid	trace
Silica	1·20
Sulphuric acid	trace
Bisulphide of iron	0·08
Organic matter	trace
Insoluble matter	3·77
	101·27

The insoluble residue contained of silica 3·73 per cent., and of alumina containing a trace of iron 0·06 per cent.; the iron contained in the ore being equivalent to 38·56. In a note appended to the analysis it is stated that no metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 1,000 grains of ore was detected.

Persons employed in Iron-mining in Durham.—Iron-mining has been chiefly confined to the district of Weardale, where a spathose and siliceous variety of hematite has long been wrought. The number of persons employed in 1854 amounted to 610. The quantity of ore raised at that time has not been recorded. In recent years the Reports of Her Majesty's Inspectors of Mines afford the necessary data, showing the numbers employed under and above ground, with the quantity of iron ore raised. These returns, it should be explained, only include those mines coming under the operation of the "Mines Regulation Act, 1872 and 1875," and do not include those workings above ground. The total output of the iron-mines of the county has already appeared under production of iron ore :—*

* Reports of H.M. Inspectors of Mines.

Year.	Persons Employed.		Total.	Iron Ore Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	266	47	313	55,981	178
1874	224	39	263	54,660	207
1875	195	29	224	45,317	202
1876	93	14	107	14,961	140
1877	118	21	139	31,858	229
1878	99	17	116	19,204	166
1879	63	10	73	8,508	116
1880	96	9	105	24,439	232

Pig Iron Manufacture.—In the Report of the British Association for the year 1863, at the Newcastle-upon-Tyne meeting, among the many interesting papers, appears one by Mr. Isaac Lowthian Bell, who gives a historical account of the manufacture of pig iron in the north of England, from which many of the following facts have been drawn.

Notwithstanding the varied character of the different ores of the district under review, and the want of indication of metallic contents of some, the property that even these have of "rusting" on exposure to air and moisture appears to have made known the existence of all at a very early period of our history. The labours of Hodgson, Wallis, and others, leave little doubt that the smelting or reduction of iron ore was carried on to a considerable extent in this part of the country during its occupation by the Romans. Vast heaps of iron scoriæ may be seen on the moors in the parishes of Lanchester and Chester-le-Street, in the county of Durham, and in the valleys of the Reed and the Tyne on the mountain limestone in Northumberland. It is remarkable that none of these are very remote from one or other of the Roman stations which are scattered over these two counties.

Hitherto all these smelting operations have reference to the small bloomery or hearth, in which a little ore was smelted by the use of charcoal, the fire being urged by the wind in exposed situations, or subsequently by rude bellows, that a "bloom" of malleable iron was obtained. The German colony of ironworkers at Shotley Bridge was established in the reign of William III., and at some time or other afterwards, a small high blast furnace, five or six feet in the boshes, was erected, the

remains of which, according to reliable information, are still visible. Wallis, in his History of Northumberland, published in 1769, mentions an iron work which existed some years previously at Lee Hall, near Bellingham, under the management of a Mr. Wood, who made a good deal of bar iron, but charcoal becoming scarce, he removed to Lancashire. Although bar iron only is mentioned, there is no doubt from the remains existing, that pig iron was also produced here. Charcoal iron was also smelted from some of the bands of clay ironstone at Bedlington, where the old calcining kilns were until recently visible. No iron, however, has, as far as can be ascertained, been made there for more than a century.

The inroads which iron-smelting and other metallurgical operations, &c., had made upon the forests were such, that in the reign of Queen Elizabeth four Acts of Parliament were passed, to restrict the consumption of timber in the manufacture of iron.

Towards the close of the last century, Mr. J. Cookson, who had recently purchased the Whitehill Estate, near Chester-le-Street, was the first to erect and work a blast furnace in the North of England with coal previously coked. The Whitehill furnace was 35 feet high, 12 feet across the boshes, and produced 25 tons of iron per week. The blast was supplied by a bellows worked by a water-wheel placed on Chester Burn. The iron made at the Whitehill furnace was used for colliery castings and Government ordnance. Frequent interruptions through want of water to drive the wheel led at length to the furnace being "gobbed" * and ultimately abandoned about the close of the last century.

Whatever advantages in point of materials any district might be possessed of, its power for turning them to profitable account depended, at that time, on the existence of a fall of water sufficient to drive the necessary blowing apparatus. The discoveries of Watt prevented the want of hydraulic power being any longer an impediment, and in a short time the obedient steam-engine was appointed to supply the necessary blast to iron furnaces.

Commencing with the present century: in the year 1800 the

* "Gobbed" or "Gobbing," a term in Metallurgy, the stopping of the blast furnace by the agglomeration of the charge within it.

Tyne Iron Company erected two blast furnaces at Lemington in Northumberland and a steam blowing-engine to impel the blast. The make of one of these furnaces in 1812 was 2,547 tons, when cold blast alone was employed, the ironstone used being obtained from the thin bands of the coal-measures of the district.

It was about this period that iron works were established at Newburn, some five miles distant from Newcastle-upon-Tyne, which in recent years have attained considerable importance. These works, now known as the Newburn Steel Works, are surrounded by much that is interesting: originally established about the year 1810 as a file manufactory by the father of the present proprietors, Messrs. John Spencer and Sons, it may be regarded as one of the oldest works in the North of England. Some of the plant put down at the period referred to yet remains, and is utilised; and an old overshot water-wheel which was originally the motive-power used, is still employed in turning a grinding-stone in the modern rolling-mill, which has taken the place of the original one. This firm, at an early period, in addition to other branches of industry, commenced the manufacture of steel by the cementation process, and in 1876 they went largely into the manufacture by the Siemens and Siemens Martin process. The three furnaces at present in operation are capable of producing 200 tons of steel per week, while two crucible furnaces of 24 pots each, equal to a production of 24 tons per week; in addition to which are also auxiliary coke crucibles of two pots each. This firm was originally the sole manufacturers of the volute springs, now so extensively used on railways as a buffer draw-spring, and still enjoys a high reputation.

The neighbourhood of Newburn possesses much of interest beyond its steel works. It was here that Stephenson lived for many years; Locke also sprung from that part, as did also the Hawthorns. Close alongside Newburn was the Wylam wagon way, which was the first plain plate railway line ever laid down. The first springs for railway purposes were made at these works, and for many years the surrounding firms were supplied with them, as well as many railways throughout the country. They were invented about the year 1847, by Mr. Baillie, also of Newcastle, who subsequently went out to Austria as chief of the state railways. At the period referred to the material employed was Swedish iron, but with the introduction of the Siemens Martin

process, a few years since, the firm were no longer dependent on other sources of supply.

The Lemington furnaces already referred to produced in the year 1823 some 2,379 tons of pig iron, from which it may be inferred that both furnaces were in blast but a part of the year. In the year 1825, iron rose in value to the unprecedented price of £12 per ton, and, a few years later, the Messrs. Perkins, Hunt, and Thompson, who were extensively engaged in coal-mining, erected two furnaces at Birtley, in Durham, near Chester-le-Street. These were put in blast in the year 1829, and in the following year produced 3,080 tons, the make of the Lemington furnaces the same year being 2,247 tons, or a total make of four furnaces in both counties of 5,327 tons. In the year 1831 the hot-blast was introduced into the works at Birtley, and in 1835 to those at Lemington, where, in the same year, was made 4,390 tons of iron, the cost of which, taken from the cost-book of the company, was as follows per ton of iron:—

	£	s.	d.
Ironstone	1	18	1¼
Flux (chalk)	0	2	7
Coal (5 or 6 tons)	0	7	0½
Labour, &c.	0	14	2¼
Sundries	0	14	2
Total	3	16	1

The growing demand for iron about this period was such, that the ore obtained from the coal-measures was insufficient to meet the requirements of the iron master, and attention was directed to other sources of supply; these were found at Grosmont, near Whitby, and in 1836 a cargo of this stone was received at the works at Birtley. Subsequently attention was directed to the deposits of ironstone occurring in the mountain limestone. Ridsdale was the place selected, from the circumstance that coal could be obtained from a seam from 2 feet to 2½ feet thick, situated in the same geological formation. Before the year 1839, the Ridsdale Company put their first furnace in blast, increasing the number to three in the year 1841. In the same year another company sprung up at Hareshaw, working the same beds of ironstone and coal, and commenced operations with one furnace, subsequently adding two to the number. The iron produced at both of the above-named works was of a good quality; but the distance of the works from railways and markets added so considerably to

the cost of the iron that they could not compete with other works, and after a few years both works were closed and finally dismantled.

The Wylam furnace was put in blast in the year 1836. About the year 1840, Messrs. Bigge, Cargill, Johnson, and others, who had purchased from the projectors of the Ridsdale Works that concern, had their attention directed to the beds of ironstone described as lying in the coal-measures near Shotley Bridge. A pair of furnaces were speedily erected and put in blast; a larger company was formed, and an immense establishment constructed. Twelve blast furnaces were built, large rolling-mills, and all the necessary mines, mining villages, &c., followed in rapid succession. Until the year 1850, the furnaces went on devouring the iron ores found in the neighbourhood at an alarming pace, having in the meantime made extensive trials of those from the lead veins of Weardale. In the year 1850, the discoveries, in Cleveland promised relief from the impending famine, and in a very short time, in spite of a distance of about 50 miles, the ironstone of that district, with some hematite for a mixture, entirely superseded the ironstone lying adjacent to the furnaces.

The Walker Works of Messrs. Losh, Wilson and Bell, established about the year 1827 for the manufacture of bar iron, were enlarged in the year 1842, when the firm extended their operations by the erection of a blast-furnace for producing forge pig by smelting their mill furnace cinders with Whitby ironstone, and this was followed by a second furnace in the year 1844. These furnaces were the first ever built for smelting the recently discovered ironstone of Whitby.

About the year 1844, the Stanhope furnace, built by Mr. Cuthbert Rippon, was put in blast, and five others were erected at Tow Law by the Weardale Iron Company, for smelting the "rider ore" (carbonate and oxide of iron) from the lead veins. There is no doubt that owing to the extreme irregularity of this kind of material, immense labour and expense were at first incurred; and, as regards the quality of the produce, frequently with very unsatisfactory results. Better acquaintance, however, with the veins and their contents has enabled that firm to produce iron of a very high class; so good, indeed, as closely to resemble in composition and quality the celebrated German iron. For bar iron purposes it bears a high name, and has, like its prototype in Germany, been found well adapted for the manufacture of the

finer kinds of steel; an application, as is well known, confined exclusively to the purer descriptions of metal.

The Witton Park Works were erected in the year 1846, in the Auckland district, by the Messrs. Bolckow and Vaughan for smelting ironstone expected to be obtained in that vicinity. These hopes were not, however, realised, and the neighbourhood of Whitby was resorted to, as it had been by almost every furnace owner in the North.

To render available the bed of ironstone occurring in the mountain limestone, furnaces were erected at Brinkburn, and also at Haltwhistle; but after some experiments both works were abandoned. Again, at Bedlington, two furnaces were erected, to smelt the same ironstone formerly used at the Charcoal Works in that locality, with an admixture of Yorkshire stone, mill cinder, and other materials; but these, also, were only a short time in operation.

The following list will show the works existing and in operation in the year 1851 in both counties, with the number of furnaces built and in blast:—

NORTHUMBERLAND.

Works.	Owners.	Furnaces.	
		Built.	In Blast.
Hareshaw*	Hareshaw Iron Co.	3	0
Ridsdale*	Ridsdale Iron Co.	3	0
Tyne or Lemington	Tyne Iron Co.	2	2
Walker	Losh, Wilson, & Bell	2	2
Witton Park	Bolckow & Vaughan	4	3
Wylam	Bell Brothers	1	1
	Total	15	8

DURHAM.

Works.	Owners.	Furnaces.	
		Built.	In Blast.
Birtley	Birtley Iron Co.	3	1
Consett and Crookhall	Derwent Iron Co.	14	7
Stanhope*	Weardale Iron Co.	1	1
Towlaw	Weardale Iron Co.	5	2
	Total	23	11

* These iron works are situated in the Carboniferous Limestone District; the others on the Coal measures.

In the year 1830, as previously stated, the make of pig iron in the above counties was 5,327 tons. In the same year the make of pig iron in England and Wales was 615,917 tons, the yield of 333 furnaces; Scotland in the same year, with 27 furnaces, producing 37,500 tons. In 1839 the five furnaces in operation in the neighbourhood of Newcastle-upon-Tyne produced 13,000 tons, giving an average yield of 2,600 tons per furnace.

About the years 1840 and 1841, a general depression of trade came about, the quotations of pig iron being very low, and prices unremunerative. Happily this state of things was of brief duration, and in the year 1844 was succeeded by a period of activity, when a great expansion of the railway system of the United Kingdom took place, causing a large demand for iron of all kinds and producing better prices. The demand for iron continued, and caused inquiries for iron ore and stone to meet it; hence the exploration of old areas, and search for new ones, containing deposits of ironstone, resulting many years later in the discovery and development of the vast fields of argillaceous corbonates of the lias in the North Riding of Yorkshire, and the hydrated peroxides of Northamptonshire and Lincolnshire. The first-named district having since greatly supplemented the requirements of the furnaces of Durham and Northumberland.

During the years from 1844 to 1847, Parliament sanctioned the construction of 9,379 miles of railway in the United Kingdom. With this, increased activity ensued to such an extent that in the last-named year the furnaces of these two northern counties produced 99,840 tons of pig iron, the details of which, with the make of each works, appear as follows :—

NORTHUMBERLAND.

Works.	Furnaces.		Make of Pig-iron.
	Built.	In Blast.	Tons.
Hareshaw*	3	2	8,320
Ridsdale*	3	2	8,320
Tyne	2	2	8,320
Walker	2	2	8,320
Wylam	1	1	4,160
Total	11	9	37,440

* Furnaces erected in Carboniferous Limestone District.

DURHAM.

Works.	Furnaces. Built.	Furnaces. In Blast.	Make of Pig Iron.
			Tons.
Birtley	3	2	8,320
Consett and Crookhall . .	14	7	29,120
Stanhope *	1	1	4,160
Towlaw	3	2	8,320
Witton Park	4	3	12,480
Total	25	15	62,400

In the same year the make of the furnaces of Great Britain was 1,999,608 tons, 433 furnaces being in blast of the total 623 built at that period. Scotland of this quantity with 89 furnaces made 539,968 tons, while England and Wales with 344 furnaces contributed 1,459,640 tons, giving an average of 4,620 tons per furnace. Advancing to the year 1852, Braithwaite Poole in his "Statistics of Commerce" gives the following details of the make of pig iron in that year in the several iron-making districts in Great Britain:—

Districts.	Furnaces. In.	Furnaces. Out.	Furnaces. Total.	Pig Iron Made.
	Nos.	Nos.	Nos.	Tons.
Durham	18	8	26	110,000
Northumberland . . .	7	6	13	35,000
North Staffordshire . .	17	4	21	90,000
South Staffordshire . .	127	32	159	725,000
North Wales	6	7	13	30,000
South Wales	135	27	162	635,000
Shropshire	27	13	40	120,000
South Wales, Anthracite	12	23	35	31,000
Yorkshire and Derbyshire.	35	7	42	150,000
Scotland.	113	31	144	775,000
Total . . .	497	158	655	2,701,000

Comparing the returns of 1852 with those for 1847, the average increase in the make rose from 4,260 tons to 5,200 tons, showing an increase of 580 tons per furnace.

In the annexed table appears the number of furnaces in blast, and the make of pig in both counties in each year since 1856:—

* Furnaces erected in Carboniferous Limestone district.

Year.	DURHAM.		NORTHUMBERLAND.	
	Number of Furnaces.	Pig Iron.	Number of Furnaces.	Pig Iron.
		Tons.		Tons.
1856	40	269,250	8	62,120
1857	35	284,500	6	63,250
1858	44	265,184	6	45,312
1859	46	370,339	6	31,500
1860	37	340,921	7	69,093
1861	32¼	312,080	7	73,260
1862	33½	337,218	6	46,586
1863	47	468,318	7	40,916
1864	42	466,980	7	55,467
1865	47	476,767	7	49,290
1866	47	298,867	6	50,456
1867	39	477,834	3	31,027
1868	35½	499,592	1	17,495
1869	40	658,506	1	15,942
1870	50¼	676,964	3	33,623
1871	47½	759,244	3	34,165
1872	49	760,172	4	38,766
1873	49¾	799,573	4	44,807
1874	49	829,235	2	33,142
1875	53	786,206	2	22,870
1876	50½	806,706	1	16,466
1877	40	734,438	1	*
1878	33	660,323	1	*
1879	31	557,255	2	*
1880	30	750,262	2	*

It will be seen from the above statement that Northumberland is passing from the list of iron-making districts; most of the works are standing and many have been dismantled, indeed the only establishment now in operation is that of Sir William G. Armstrong and Co., at Elswick. Durham, on the other hand, has greatly augmented her resources.

In the annexed table appears the list of iron works in the past year, showing the number of furnaces built and in blast :—

NORTHUMBERLAND.

No.	Name of Works.	Owners.	FURNACES.	
			Built.	In Blast.
			Nos.	Nos.
1	Elswick, Newcastle-on-Tyne .	Sir W. G. Armstrong & Co. .	2	2
2	Walker, " . .	Bell, Brothers, Limited . . .	2	0
		Total	4	2

* Included in the return for Durham.

DURHAM.

No.	Name of Works.	Owners.	FURNACES. Built.	FURNACES. In Blast.
			Nos.	Nos.
1	Carlton, Stockton-on-Tees	The Carlton Iron Co., Limited	3	3
2	Port Clarence, Middlesbro'-on-Tees	Bell, Brothers, Limited	12	12
3	Consett, Durham	Consett Iron Co., Limited	7	6
4	Ferry Hill	Rosedale and Ferry Hill Iron Co., Limited	10	0
5	Jarrow-on-Tyne	Palmer's Iron Co., Limited	3	3
6	Middleton, Darlington	George Wythes & Co.	4	0
7	Norton, Stockton-on-Tees	Norton Iron Co., Limited	6	0
8	Vane and Seaham	Watson, Kipling & Co., Limited.	2	0
9	South Durham, Darlington	South Durham Iron Co., Limited	3	0
10	Towlaw, Darlington	Weardale Iron Co., Limited	4	0
11	Tudhoe, Spennypoor	"	2	0
12	Wear, Washington	Bell, Brothers, Limited	1	0
13	West Hartlepool	West Hartlepool Iron Co., Lim.	3	0
14	Witton Park, Bishop Auckland	Bolckow, Vaughan & Co., Lim.	6	3
15	Stockton, North Shore	Stockton Iron Furnace Co., Lim.	3	0
16	Tees Bridge, Stockton	Tees Bridge Iron Co., Limited	3	3
		Total	72	30

Malleable Iron Works and Coal used.—Mills and forges:—The production of the various forms of malleable iron in the north of England may be said to date from the middle of the last century. Coming down to more recent times, Mr. Isaac Lowthian Bell, in the year 1863, remarks,* "It is obvious that in a country where, comparatively speaking, there would be a considerable consumption of wrought iron, there was necessarily thrown into the market a corresponding quantity of old or scrap iron. With cheap fuel, and water power in sufficient quantity to drive small hammers, forges were erected at various suitable localities, such as Smallwell by Messrs. Crowley and Co.; Beamish and Lumley, by Messrs. Hawks; Bedlington, and at various other places." The last named works were projected about the year 1809; and it was at these works in the year 1820 that malleable iron rails were first rolled by the invention of a Mr. Birkenshaw. The works at Bedlington were laid down by a Mr. Longridge, the River Blythe supplying the necessary motive power.

The next stage in the manufacture of malleable iron, following the introduction of small hammers and forges, was the erection of slitting mills. It is stated by Mr. Stephen Hawks that these

* "British Association Papers on the Manufacture of Iron."

slitting mills were first used at the Gateshead Iron Works about the year 1772, and were brought from London, and probably were manufactured in Wales or in the Midland Counties. Slit rods, it appears, were first made in the north of England from hammered bars. The late Mr. William Losh, one of the founders of the firm of Losh, Wilson and Bell, erected a slitting mill near Newcastle; the iron he used was imported from Sweden; this was about the year 1800. Cort patented the rolling of bar iron in the year 1783, and Mr. Stephen Hawks in an old letter book of 1799, finds Mr. William Hawks writing:—"We will certainly roll the iron to the dimensions you mention;" so that probably rolling mills were introduced into the neighbourhood of Newcastle-upon-Tyne a very short time after their invention by Cort. In the year 1800 a small mill appears to have been erected at Lemington.

In the year 1827 Messrs. Losh, Wilson, and Bell, erected what was at that time considered in the North a powerful mill at Walker, capable of rolling from 80 to 100 tons of bars per week. Here, as at all the other works, old scrap iron, or common Welsh bars, cut up for re-rolling, were the raw materials used. This firm led the way in extending the operations to the puddling of pig iron, a process adopted by them in the year 1833. The rapid progress in Scotland of the manufacture of pig iron from black band ironstone by means of hot-blast, and the cheapness of coal on the Tyne, induced Messrs. Losh, Wilson, and Bell, to increase their rolling power. A second mill was erected in the year 1838, where rails of the largest dimensions, and tyre-bars for the wrought iron wheels, invented by Mr. Losh, were manufactured. The old house of Hawks and Company soon after added largely to their means of producing wrought iron. In this they were speedily followed by the Derwent Iron Company, who erected immense rolling-mills at Consett, near Shotley Bridge, and increased largely the capabilities of the Bishopwearmouth Iron Works which they had previously purchased. There would be in the district previous to the year 1850 about 300 puddling furnaces, capable of turning out about 150,000 tons of finished iron per annum.

The foregoing works and others, subsequently established from time to time, increased their appliances for producing the various forms of malleable iron, until, in the year 1862, there appear to

have been 17 works in operation, possessing an aggregate of 646 puddling-furnaces, the producing power of these works being estimated by competent authorities as being equal to the manufacture of 340,000 tons of finished iron, and probably the actual make during the year 1862 may have reached 300,000 tons. It further appears that in addition to the iron obtained by the puddling process, a considerable weight of iron is also manufactured in these works from old iron imported into the district from various parts of the kingdom.

Without going into details as to the precise date at which the several important works established in rècent years were projected and erected, contributing so much to the welfare and prosperity of the north of England, the year 1872 may be taken as one of great prosperity. At this time there appear to have been 22 works in Northumberland and Durham, making the various forms of malleable iron, plates, rails, angles, sheets, &c., possessing 1189 puddling furnaces and 66 rolling mills, and at the Tudhoe Works of the Weardale Iron and Coal Co., Bessemer plant consisting of four convertors, each with a capacity of 50 cwts. In all these works in 1872 the ascertained quantity of coal employed was 1,259,000 tons. In the year 1873 the same works numbered 1194 puddling furnaces, the rolling mills and Bessemer convertors stood as in the previous year, the quantity of coal used in manufacture increasing to 1,264,000 tons.

In the year 1877 the number of works stood at 28, of which 22 were more or less actively employed, with 1319 puddling furnaces, and 89 rolling mills.

The British Iron Trade Association, in their report for the year 1877, give the total production of manufactured iron in Great Britain as 1,794,000 tons, of which quantity Northumberland, Durham, and Cleveland produced 405,000 tons; South Staffordshire, 365,000 tons; Scotland, 218,000 tons; Lancashire, 200,000 tons; Leeds, Bradford, Sheffield, and Rotherham, 266,000 tons; and other districts the remainder.

The production of 1878 and 1879 was somewhat in excess of the preceding year. The returns for the Durham and Cleveland districts in 1880 amounted to 508,000 tons, an increase of 200,000 tons over the production of 1879. In the year 1880 the works erected and in operation, with the names of proprietors and resources of mills and forges, were as follows :—

DURHAM AND NORTHUMBERLAND.

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Auckland	Thomas Vaughan & Co.	Bishop Auckland	..	..
2	Whessoe	" "	Darlington	..	..
3	Hartlepool	Hartlepool Rolling Mills Co., Limited	West Hartlepool	34	2
4	Jarrow	Palmer's Shipbuilding and Iron Co., Limited	Newcastle	72	7
5	Albert Hill	Darlington Iron Co., Lim.	Darlington	..	..
6	Springfield	" "	"	..	..
7	Birtley	Birtley Iron Co.	Chester-le-street	..	..
8	Consett	Consett Iron Co., Limited	Durham	167	6
9	Fence Houses	Hopper, Radcliffe, & Co.	Fence Houses	..	..
10	Gateshead	Hawks, Crawshay, & Sons	Gateshead	65	5
11	Hive	John Elliot & Son	East Jarrow	..	..
12	Monkwearmouth	Samuel Tyzack & Co.	Sunderland	27	2
13	Tudhoe	Weardale Iron and Coal Co., Limited	Spennymoor	..	..
14	Skerne	Skerne Iron Works Co., Limited	Darlington	72	4
15	West Hartlepool	West Hartlepool Iron Co., Limited	Hartlepool	..	..
16	Rise Carr	Fry, Janson & Co.	Darlington	32	3
17	Stranton	Robert H. Charlton	West Hartlepool	..	..
18	Stockton	Stockton Malleable Iron Co., Limited	Stockton	78	10
19	Park	John Abbot & Co., Lim.	Gateshead	32	3
20	Albion (Felling Shore)	Fellling Coal, Iron, and Chemical Co., Limited	"	..	..
21	Thornaby	W. Whitwell & Co.	Stockton	31	5
22	Carr House	Dunlop, Meredith, & Co., Limited	West Hartlepool	..	.
23	Walker	Bell, Brothers	Walker	..	..
24	Witton Park	Bolckow, Vaughan, & Co., Limited	Stockton	104	6
25	South Hylton	Raine, Brothers	South Hylton	..	..
26	Richmond	R. Jaques & Co.	Stockton	24	3
27	West Stockton	West Stockton Iron Co., Limited	"	..	..
28	Stockton	R. S. Johnson & T. M. Reay	"	22	3
	Total of County			761	59

In considering the resources of the mills and forges in the north of England, it appears that the majority of the works, employing about two-thirds of the puddling furnaces, are more or less dependent upon the open market for the purchase of all their materials, being exclusively finished iron works, without the adjuncts of blast furnaces, mines, or collieries; while the remaining works have the command of their own pig, and, in some cases, their own coal, which gives these latter works a more favourable basis for operation.

In the years 1872 and 1873 the quantities of coal used in the malleable iron works were approximately ascertained; since that date, however, the data available are not so complete as could be desired, in a great measure due to the general depression prevailing; however, it may be generally stated that in the north of

England each puddling furnace, when actively employed, consumes from 1,200 to 1,300 tons of coal, and will yield 500 tons of bars or rails per annum with the consumption of this quantity of fuel.

Coal and Iron Ore used in Manufacture.—In considering the question of the quantities of coal and ore used in the make of pig iron, it will be convenient to deal with the two districts collectively rather than make each the subject of a separate inquiry. About the year 1840 Mr. William Jessop, of the Butterley Iron Works, Derbyshire,* in his inquiry, ascertained that in each ton of pig iron made in those districts, 3½ tons of coal were employed. The result of the Royal Coal Commission inquiry determined the average quantity employed throughout the country, all purposes included, did not exceed 3 tons, while the returns of later years to the Mining Record Office exhibit a still greater economy. In the year 1873 the average did not appear to exceed 45 or 46 cwts., in these districts, the average for Great Britain probably not exceeding 57 cwts. in the same year. The economy in the consumption of fuel has thus within a few years greatly increased, and since special interest now attaches to this subject it may be reasonably expected that the returns of each successive year will exhibit further economy in the coal used in this important branch of our iron manufactures.

In the table below appear the total quantities of pig iron made, and of coal and ironstone used in Durham and Northumberland in each year since 1872 :—

Year.	Pig Iron.	Coal Used.	Iron Ore.
	Tons.	Tons.	Tons.
1872	798,938	1,890,766	2,623,895
1873	844,380	1,949,447	2,870,791
1874	862,377	2,047,768	2,917,683
1875	809,076	1,908,240	2,784,428
1876	823,172	1,895,402	2,829,669
1877	734,438	1,656,056	2,407,834
1878	660,323	1,386,601	2,097,430
1879	529,559	1,161,587	1,487,202
1880	750,262	1,420,766	2,069,243

An examination of the above figures shows some interesting facts ; thus, in the year 1872 and 1873, the average make of the

* For details of Mr. Jessop's return, see Appendix, pp. 835, 836.

furnaces was in the Durham District 15,574 tons and 16,071 tons respectively, compared with 18,366 tons in the year 1877, and 19,421 tons in the year 1878. The proportion of coal in 1872 to each ton of pig iron made was a consumption of 47¼ cwts., comparing favourably with the return of the years 1878 and 1879, when 42 cwts. of coal previously coked was the amount employed, all purposes included, in the production of each ton of pig iron.

The great bulk of the ironstone now smelted in the Durham furnaces is obtained from the Cleveland district; the other ores employed in admixture are obtained from the west coast hematites of Lancashire and Cumberland, the local ores from Weardale, and some small quantities from distant districts and foreign countries. The Cleveland ore so extensively used would, if alone employed, require 70 cwts. of raw uncalcined stone to produce 20 cwts. of pig iron, but with the admixture of foreign ores, rich in metallic iron, the actual quantities in 1872 and 1873 did not exceed from 67 to 68 cwts., while in the year 1878 the quantity, as shown by the figures above, amounted to but 63½ cwts. of ironstone of all varieties to each ton of pig iron made.

The sources from whence the ores used in the years 1872 and 1873 were obtained were as follows. Side by side appear corresponding data for the four years ending 1880:—

Localities.	1872.	1873.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Cleveland . .	2,100,000	2,392,000	1,972,395	1,642,149	1,253,850	1,603,905
Cumberland . .	85,139	44,281	46,087	37,896	8,203	8,289
Lancashire . .	58,096	37,821	10,897	19,992	2,753	23,904
Northamptonshire	20,000	25,000	*	*	*	1,106
Weardale, &c. .	128,471	123,282	115,523	40,144	16,461	41,357
Foreign ores .	182,189	188,407	142,932	210,685	131,487	342,150
Other ores . .	50,000	60,000	120,030	146,564	74,448	48,532
Total . .	2,623,895	2,870,791	2,407,834	2,097,430	1,487,202	2,069,243

The last item, "other ores," includes ores derived from various localities not ascertained, also "purple ore," an oxide of iron, obtained from the metal extraction works, and containing from 62 to 67 per cent. of metallic iron.

* Quantities included under other ores.

The foreign ores enumerated above were received at the following ports in the years stated :—

Ports.	1872.	1873.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Berwick . .	..	150	..	..	..	70
Hartlepool . .	33,418	13,850	401	2,341	1,038	327
Newcastle . .	82,979	114,966	70,097	134,320	62,613	152,664
Shields, North .	9,562	15,044	6,987	6,618	5,171	12,770
Shields, South .	20,149	20,564	21,802	13,950	22,263	44,413
Stockton . .	2,229	440	420	1,919	9,046	59,357
Sunderland . .	33,857	23,393	43,225	51,537	31,356	72,549
Total . .	182,189	188,407	142,932	210,685	131,487	342,150

The total imports of iron ore into the United Kingdom in each of the same years with the declared value at the port of import being as follows, showing the high character of the ore—the value exceeding 20*s*. per ton :—

Year.	Quantities.	Value.
	Tons.	£
1872	576,264	671,926
1873	967,536	1,278,278
1874	754,147	1,021,481
1875	458,673	583,571
1876	672,235	795,516
1877	1,142,308	1,256,069
1878	1,173,411	1,162,851
1879	1,083,692	1,037,719
1880	2,634,401	2,792,717

Spain, in 1880, furnished the great bulk of the ores imported. The ore is of carboniferous limestone age, and is extensively developed in the Sommorrostro Mines, near Bilbao, as well as in other districts. The extent of the industry will be understood from the fact that during the year 1878 the total quantity of iron ore exported from the port of Bilbao amounted to 1,224,730 tons, of which quantity England received 856,038 tons and Scotland 47,445 tons, according to a Spanish official return. In the year 1870 the Spanish ores imported amounted to 179,083 tons, of the value of £146,717, compared with 99,816 tons, valued at £78,134, in the previous year. In subsequent years the total quantities and values of Spanish ore imported into Great Britain is recorded as under,* the diminished imports in the intervening

* Trade and Navigation Returns.

years being accounted for by the disturbed state of that country:—

Year.	Quantities.	Value.
	Tons.	£
1871	302,382	284,255
1872	631,134	705,441
1873	790,891	1,000,720
1874	541,963	665,614
1875	250,641	273,757
1876	522,383	556,756
1877	990,029	983,556
1878	1,088,862	1,021,455
1879	1,007,617	918,276
1880	2,278,962	2,270,462

Official returns recently published show that in the year 1880 the total iron ore exported from Bilbao amounted to 2,345,598 tons. Of this quantity 1,557,000 tons were conveyed to England, and 112,000 tons to Scotland, the remainder being sent coastways and exported to other countries. The first half of the year 1881, ending June, according to the Customs returns of Bilbao, show the iron ore industries to be in a flourishing state; up to that date 1,325,000 tons having been exported, the average prices delivered F. O. B. varying from 8·50 to 8·75 francs per ton.

CHAPTER II.

YORKSHIRE (WEST RIDING) IRON INDUSTRIES.

Ironstone of the Coal Measures—Analyses and Production of Ironstone—Pig Iron Manufacture—Early History—Annual Production—Works in operation—Bessemer Steel Works—Coal and Iron ore used in Manufacture of Pig Iron.

Yorkshire (West Riding) Ironstone Measures.—Independent of the coal seams, and interstratified with them, are numerous bands or seams of ironstone, in the northern divisions of the coal-field situate in the West Riding of Yorkshire. In the neighbourhood of Bradford and Leeds the mineral field is well developed, and has given rise to the establishments of Bowling, Low Moor, Bierley, and others. The more important of the ironstone measures in the districts above referred to are those of the White Bed Mine (Bierley); and the Black Bed Mine, or Low Moor bed of ironstone worked extensively between Low Moor and Leeds; there is however considerable irregularity in the thickness of these beds, and in the distribution of the nodules, and hence a variation in the yield of ironstone. The White Bed Mine at Bierley yields an average of 1,200 tons of ironstone per acre; the Low Moor Bed is much more productive. These beds of ironstone consist of a series of bands known as follows:—

WHITE BED MINE.	BLACK BED MINE.
BIERLEY.	LOW MOOR.
Top Flatts.	Top Balls.
Low Flatts.	Flat Stone.
White Balls.	Middle Balls.
Middle Balls.	Rough Measure.
Low Measure.	Low Measure.
	Basset Stone.

Beneath these beds of ironstone of which the White Bed Mine is uppermost, lies a seam of coal not exceeding two feet in thickness, locally known as the "better bed," remarkably free from impurities, more especially iron pyrites, and consequently containing but a small percentage of sulphur, which renders it of

great value in the manufacture of iron. Beneath the "better bed" coal occurs a valuable seam of indurated fire clay, varying from two to three feet in thickness. This fire-clay furnishes a superior quality of fire-brick, and is also much used as a lining in the blast furnace.

Southwards, by Wakefield, Barnsley, Rotherham, and Sheffield, this mineral field is extremely rich in its ironstone and coal, to a depth of upwards of 300 yards. In the top of the series occurs the Barnsley Thick Coal, which varies in thickness from 6 feet to 9 feet 6 inches, and at the bottom occurs the Silkstone seam of coal 4 feet thick. Between the above named seams of coal are others of less thickness, and the following ironstone measures in descending order:—

1. *Swallow Wood Mine* (Milton).—Consisting of three bands, of Flatts, Balls, and Bottom Measures, and yielding about 1,500 tons of ironstone per acre. *Swallow Wood Coal.*
2. *Lidgate Mine* (Milton).—Consisting of three bands, Flatts, Balls, and Bottom Measures, and yielding 1,800 tons of ironstone per acre.
3. *Tankersley Mine* (Milton).—Consisting of Top, Middle and Bottom Measures, and yielding from 2,000 to 3,400 tons of ironstone per acre. *Deep End Coal.*
4. *Thorncliffe* or *Old Black Mine* (Parkgate).—Consisting of Balls, Holing Measures, in all 11 inches of ironstone, and yielding 1,500 tons of ironstone per acre. *Parkgate* or *Manor Coal.*
5. *Thornecliffe, White Mine* (Parkgate).—Consisting of Flatts, Balls and Holing Measures, and yielding 1,500 tons of ironstone per acre. *Thorncliffe Thin Coal.*
6. *Black* or *Clay Wood Mine* (Parkgate).—Consisting of Balls, Brown George, and Whetstone Measures. *Silkstone Coal.*

Analyses of the Ironstones.—These clay ironstones, or argillaceous carbonates of iron, in the districts above referred to vary but little in their general character and composition; they have all been carefully examined and the results published in the "Memoirs of the Geological Survey."* The analyses were made by Mr. John Spiller, in Dr. Percy's Laboratory of the Royal School of Mines, by whom the several measures are thus described and the composition determined.

White Bed Mine—The sample examined consisted of equal weights of five specimens of this ironstone measure, described as

* "Iron Ores of Great Britain," Part I., 1856, pp. 66, 69.

a "clay ironstone of varying colour, from a light brown gray to black gray;" the shades deepening in intensity with the order of the specimens selected. Two of the samples exhibited a conchoidal fracture, had a closer texture, and were harder than the others; in another a vein of iron pyrites occurred.

Black Bed Mine, Low Moor.—The sample examined consisted of six specimens of this measure, in the proportion of equal weights; all the samples are described as "dark blackish gray clay ironstones," two varieties being harder than the rest, one variety showing thin films taking the form of shells and containing iron pyrites. The analyses exhibit the following constituents:—

RESULTS TABULATED.

Constituents.	White Bed Mine.	Black Bed Mine.
Protoxide of iron . .	35·38	36·14
Peroxide of iron . .	1·20	0·61
Protoxide of manganese .	0·94	1·38
Alumina . . .	0·80	0·52
Lime	2·78	2·70
Magnesia . . .	2·22	2·05
Carbonic acid . . .	25.41	26·57
Phosphoric acid . .	0·48	0·34
Sulphuric acid . . .	trace	trace
Bisulphide of iron . .	0·18	0·10
Water hygroscopic . .	0·74	0·61
,, combined . .	1·11	1·16
Organic matter . . .	0·23	2·40
Insoluble residue . .	28·00	25·27
	99·47	99·85
INSOLUBLE RESIDUE.		
Silica	19·13	17·37
Alumina	6·83	6·22
Peroxide of iron . .	0·57	0·84
Lime	0·11	trace
Magnesia	0·07	0·12
Potash	0·78	0·65
	27·49	25·20
Metallic iron . . .	28·76	29·12

A distinct trace of copper was detected in 500 grains of the White Bed Mine, while in 600 grains of the Black Bed Mine

none of the metals precipitable by sulphuretted hydrogen from the hydrochloric acid solution were found.

The ironstone measures in the southern division of the West Riding of Yorkshire worked at Parkgate, very similar to those above described of Bierley and Low Moor, have been also examined, the samples in each case consisting of equal weights of each ore: the composition of each mine being as follows:—*

RESULTS TABULATED.

Constituents.	THORNCLIFFE.		PARKGATE.
	Old Black Mine.	White Mine.	Black or Clay Wood.
Protoxide of iron	41·77	39·38	39·87
Peroxide of iron	1·96	1·24	0·53
Protoxide of manganese	1·13	0·95	1·38
Alumina	0·58	0·82	0·74
Lime	2·55	2·26	2·12
Magnesia	3·71	3·72	2·64
Carbonic acid	31·39	29·38	28·47
Phosphoric acid	0·75	0·47	0·69
Sulphuric acid	trace		trace
Bisulphide of iron	trace	trace	0·05
Water hygroscopic	0·55	0·68	0·59
,, combined	1·15	1·41	1·21
Organic matter	0·86	0·54	0·83
Insoluble residue	14·16	19·35	20·30
	100·56	100·20	99·42
INSOLUBLE RESIDUE.			
Silica	8·93	12·16	13·50
Alumina	4·21	5·60	5·39
Peroxide of iron	0·43	0·45	0·77
Lime	trace	trace	trace
Magnesia	0·14	0·17	0·13
Potash	0·43	0·37	0·18
	14·14	18·75	19·97
Metallic iron	34·16	31·82	31·92

The average yield of the ironstones wrought in the West Riding of Yorkshire may be taken at 32 per cent. of metallic iron. These ores, before calcination takes place, are usually exposed to the air, when the adhering particles of shale disin-

* "Iron Ores of Great Britain," Part I., 1856, pp. 71 73, 75.

tegrate, and their removal is easily effected. In the operation of calcination they lose from one-third to one-fourth of their weight, the loss consisting of carbonic acid and water.

Thirty years ago the argillaceous ores of the coal measures furnished between 60 and 70 per cent. of the ores smelted in our iron works; since that period, with the development of the deposits in the carboniferous limestone of the West coast in Lancashire, and Cumberland, and of the Liassic and Oolitic formations in the North Riding of Yorkshire and Northamptonshire, new sources of supply have opened up, supplemented by the imports of valuable hematites from foreign countries, so much so, that the proportion of clay ironstone now employed does not exceed 36 per cent. compared with 60 or 70 per cent. in the year 1850. The clay ironstones available for reduction in 1879 amounted to 5,130,849 tons, other ores 9,248,886 tons; while the ores imported amounted to 1,085,045 tons, of the value of £1,050,167; making a total of 14,379,735 tons operated upon in the blast furnaces of the United Kingdom.

Production of Ironstone.—The earliest returns of the production of the ironstone measures in the West Riding of Yorkshire were published for the year 1855,* when the total quantity raised amounted to 255,000 tons. In the year 1856 the production was but 242,100 tons, of which quantity the collieries in the neighbourhood of Leeds produced 42,600 tons. In subsequent years the returns appear as follows:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1857	207,500	1865	575,000
1858	189,750	1866	357,000
1859	175,000	1867	579,000
1860	255,700	1868	785,028
1861	235,500	1869	230,905
1862	350,500	1870	307,717
1863	475,000	1871	407,997
1864	555,000	1872	466,305

These returns show great fluctuations, the year of greatest production being 1868, since which date a considerable falling off appears.

The details of production for the three years ending 1872 appear as follows:—

* Mineral Statistics of the United Kingdom.

District or Mine.	1870.	1871.	1872.
	Tons.	Tons.	Tons.
Bowling	36,221	36,083	46,651
Farnley	14,000	25,983	26,759
Kimberworth . .	2,496	1,730	...
Low Moor. . . .	68,000	75,437	80,000
Thorncliffe . . .	...	...	15,497
West Ardsey . . .	37,000	...	...
White Horse. . .	...	18,764	17,398
Sundry Mines . . .	150,000	250,000	280,000
Total. . .	307,717	407,997	466,305

Since 1872 the ironstone raised is seen in the following quantities, together with its value:—

Year.	Quantities.	Value.
	Tons.	£
1873	407,388	122,216
1874	370,960	154,074
1875	353,582	159,089
1876	381,463	228,877
1877	402,746	241,647
1878	370,405	185,202
1879	321,789	160,894
1880	286,698	143,349

From the above it appears the average value of these argillaceous ores varied from 6*s*. per ton in 1873, increasing to 12*s*. per ton in 1877 and 1878, and since that date show a falling off to 10*s*. per ton.

Pig Iron Manufacture.—The early history of this industry is closely identified with the town of Bradford. Although evidence exists of the smelting of the argillaceous ores of the coal measures at a remote period, on a limited scale, yet it may be said in modern times to date from the year 1780 or 1781, when the Bowling Company purchased the Manor of Bowling, with its ancient hall, and laid the foundation of the works which in subsequent years have attained such a wide-spread reputation. The operations of the company in the early years of its existence were confined more especially to foundry and smith's work. It was not till the year 1788 that the furnaces erected under the superintendence of Mr. John Sturges, of Sandall, near Wakefield, were put in blast and the smelting of iron ore commenced. And here it will be interesting to note a few facts showing the magnitude

of the Bowling Works in the present day. These works comprise six cold blast furnaces, from which about 360 tons of pig iron are run per week, 5 refineries, 21 puddling furnaces, 40 heating furnaces, an extensive forge, a tyre mill for rolling steel and iron weldless tyres, one guide mill, one bar mill, with 15 in. rolls and tin plate mills.

The Bowling estate itself supplies almost all the coal and ironstone which the company consumes, its collieries extending five or six miles in various directions, and the main pits being connected together and with the iron works by tramways worked with wire ropes. The total length of these tramways is 21 miles, the number of pits 42, and the number of hands employed in them is more than 2,000. To work the pits 61 steam-engines are required, having cylinders varying from 7 to 70 inches in diameter; and to supply them with steam 81 boilers are required of from 10 to 50 horse power each. In the iron works are three blast engines, with blowing cylinders, varying from 76 to 84 inches in diameter; and 14 engines, of from 20 to 60 horse power, to give motion to the various machines, besides numerous small steam-engines driving separate machines, and pumping water for the boilers. The number of steam-hammers is 13, and helve hammers 2. The supply of steam is maintained by 33 boilers of from 20 to 50 horse power each. The number of hands employed at the iron works is upwards of 1,000, thus making a total of 3,000. There is also an extensive steel works for making crucible steel, having about 100 pot furnaces, besides furnaces on the Siemens and Siemens Martin principle, worked by the Siemens regenerative gas furnace.*

The distinguishing qualities of the Bowling iron are hardness with great pliability, homogeneity, and uniformity of texture, capability of withstanding the action of fire, and receiving a brilliant polish; these special qualities cause the iron to be in great request in the numerous industries abounding in Sheffield, where it is extensively employed. Mr. Wilcox, in his interesting paper referred to, concludes by remarking, "that works established in the infancy of the iron trade, and producing a superior quality of metal—quality being always preferred to quantity whenever the alternative presents itself—must naturally be dis-

* Mr. Joseph Wilcock's paper on "The Bowling Iron Works," British Association Reports, 1873. Bradford Meeting.

posed to conservatism. Besides, repeated experiences have proved the necessity of keeping to the original mode of working with the minerals and iron. It is rarely known to what purposes or tests, the iron may be put on leaving the premises, but it is known it will have to withstand usage such as common iron, or any other iron but charcoal iron perhaps could do, and it was for the latter that the Bowling iron was originally manufactured as a substitute."

Returning to the founding of the iron works in the West Riding of Yorkshire, as previously stated, the Bowling works were projected in the year 1780. The Low Moor works were established in the year 1790; and a writer in London Society* gives the following interesting sketch of its founder, Mr. Joseph Dawson:—

"It was probably due more to the investigation and recommendation of Mr. Dawson than to anything else that the Low Moor enterprise was entered upon. Mr. Dawson was an intimate friend of Dr. Priestly, and a man of high scientific attainments. He had given much attention to metallurgy and chemistry, and had watched the progress of scientific discovery in regard to the working of iron with keen interest. He was a man of great vigour of mind and originality of character. In 1768 he was ordained minister of Upper Chapel, Idle; and was then in his twenty-ninth year, and had just been married. Born in very humble circumstances he was led to make energetic efforts to educate himself and attracted the notice of a gentleman, who generously took him by the hand and found the funds for the lad's educational training at the Daventry Academy. Mr. Dawson did not make a successful minister; his mind was too much occupied in scientific speculation, and in the promotion of his material prosperity. He established some coal mines on the hill-side near his chapel and worked them with profit. It was averred that his spiritual ministrations and his commercial engagements trenched so closely upon each other that he used frequently to be found paying his colliers their wages on the Sunday morning before service; after which he would slip into the little chapel and read to his handful of hearers a few pages from a sermon book that had previously been placed in readiness in the pulpit. He was a farmer as well as a colliery proprietor, and minister of the Gospel. His hens were penned in the chapel

* October, 1879.

grave-yard, and the fodder for his cattle was stowed away in a portion of the chapel itself. His duties and engagements were, indeed, of a multifarious character, and he was looked up to by the villagers for assistance and counsel in all kinds of difficulties. He was skilled in the profession of medicine, and was regularly called upon to prescribe for the benefit of his neighbours in times of sickness. It was no wonder that a man who had so many engagements apart from his ministry, should find his congregation gradually dwindling. The Sunday attendance in the chapel was sometimes not more than half a dozen, and so matters went on until the Low Moor enterprise began to occupy his thoughts, when he relinquished his spiritual charge and thenceforth was to all intents and purposes a man of business."

Following the Low Moor Works, those at Shelf, near Halifax, were projected about the year 1795, commencing the manufacture of pig iron; these works were acquired at a later period by the Low Moor Company, while in the year 1797 the Rotherham Works were established.

The make of pig-iron in the West Riding of Yorkshire in the year 1740 was but 1,400 tons, presumably charcoal iron, the yield of six furnaces. In the year 1788 there appears to have been one furnace making charcoal iron, and six furnaces making coke pig iron, the former producing 600 tons and the latter 4,500 tons, or a total of 5,100 tons in 1788. Another return gives the make of the Bowling furnaces, between the years 1795 and 1798, as about 2,000 tons per annum. The make of the Low Moor furnaces about the same period being 2,573 tons in 1795, and 2,658 tons in the year 1798; the works at Shelf in 1798 are stated to have made 3,442 tons, while those at Rotherham produced 3,000 tons.

The total make of pig iron in England and Wales in 1788 was 61,300 tons, of which 13,100 tons were charcoal pig and 48,200 tons coke pig iron.

The information arising out of the inquiry instituted in the year 1796, when Mr. Pitt proposed to levy a duty on coals at the pit's mouth, presents the following facts bearing on the make of pig iron at this period. The return referred to appears under three heads, the figures in the last column being accepted as the quantities produced. The names of the Yorkshire works, and the number of furnaces are also given with details of production:—

Works.	Number of Furnaces.	Excise.	Supposed.	Exact.
		Tons.	Tons.	Tons.
Bowling	2	2,000	2,000	2,000
Wibsey Moor . .	2	2,000	2,000	2,500
Shelf.	1	1,000	1,000	1,140
Birkenshaw . . .	1	780	780	846
Thorncliffe . . .	2	1,092	1,092	712
Elsecar	1	800	800	950
Bretton	1	250	250	250
Holmes	3	6,000	6,000	2,000
Total . . .	13	13,922	13,922	10,398

Ten years later another return is available, giving the number of furnaces in the district as 26, of which 22 were in blast, making 27,646 tons of pig iron.

In the return for 1796 the total production of the furnaces of Great Britain as ascertained appears thus, giving an average per furnace of 1,000 tons per annum :—

	Furnaces.	Pig Iron.
	Nos.	Tons.
Excise	124	167,311
Supposed	124	152,545
Exact	124	125,079

The following gives the works, furnaces, and owners, as well as the make of pig iron at each works in the year 1806 :—

Works.	Owners.	Furnaces.		Pig Iron Made.
		Built.	In Blast.	
		Nos.	Nos.	Tons.
Sheffield Park. .	Booth & Co. . . .	1	1	1,905
Chapel Town and Swallow Hill .	Swallow & Co. . .	3	1	3,737
Thorncliffe . .	Chambers & Co. . .	2	2	2,500
Bowling . . .	Sturges & Co. . .	3	2	2,473
Low Moor . .	Jarratt & Co. . .	4	4	5,143
Shelf	Haydon & Co. . .	3	2	2,716
Birkenshaw . .	Emmett & Co. . .	1	1	612
Renishaw . . .	Appleby & Co. . .	1	1	975
Elsecar . . .	Darwen & Co. . .	2	2	2,495
Bretton . . .	Cook & Co. . .	1	1	250
Holmes and Milton.	Walker & Co. . .	3	3	3,000
Calden . . .	Emmett & Co. . .	1	1	1,040
Fieldhead . . .	Parker & Co. . .	1	1	800
	Total . .	26	22	27,646

The Renishaw Works clearly belong to Derbyshire, and diminish the make of pig iron in Yorkshire by 975 tons, giving a total of 26,771 tons, and the number of furnaces as 21, being an average of 1,275 tons per furnace.

The make of pig iron in Great Britain in the same year was 243,851 tons, there being 161 furnaces in blast, of the 216 furnaces built.

Not again until the inquiry instituted by the Government and presided over by Mr. F. Finch, in the years 1831–32, does any record appear indicating the progress of the iron industry. The result of Mr. Finch's inquiry does not show any great expansion of the iron trade since the year 1806, which will appear from the following returns of production for each of the years 1823 and 1830 in the Yorkshire furnaces:—

Furnaces.	1823.		1830.	
	Number of Furnaces.	Pig Iron Made.	Number of Furnaces.	Pig Iron Made.
		Tons.		Tons.
Bowling	3	5,366	3	5,117
Brierley	1	2,450	2	4,590
Chapel Town	1	1,400	1	1,631
Elsecar	3	1,400	3	1,460
Holmes	3	2,000	3	1,000
Low Moor	4	6,200	4	...
Shelf	3	...	3	7,480
Milton	2	2,187	2	1,715
Sheffield Park	2	2,018	2	2,081
Thorncliffe	3	2,909	3	2,188
Worsborough	1	1,381	1	1,664
Total	26	27,311	27	28,926

The total make of pig iron in Great Britain in 1823* was 455,166 tons and 678,417 tons in 1830, the number of furnaces in each of the same years being respectively 266 and 372, showing an increase in seven years of 106 furnaces and 223,251 tons; the increase in Yorkshire being one furnace and 1,615 tons.

Advancing to the year 1839, Mushet † gives the make of 22 furnaces as 52,416 tons. In 1840 Mr. William Jessop, of the Butterley Iron Works, Derbyshire, ascertained that the Yorkshire furnaces,

* For details, see Appendix II., p. 834.

† Papers on "Iron and Steel," p. 421.

25 of which were in blast out of 32 built, made 56,000 tons of pig iron; the total make of pig iron in Great Britain the same year being 1,396,400 tons, the yield of 402 furnaces out of a total of 490 furnaces built. A few years later, in 1843, the returns show a falling off in production to the extent of 181,050 tons, the make in 1843 being 1,215,350 tons compared with 1,396,400 tons in 1840; the only districts in which an increase appears were those of Northumberland and North Staffordshire, amounting to but 16,000 tons. On the other hand in South Staffordshire the falling off was 106,900 tons, and in South Wales 47,650 tons in the period referred to, which was one of great commercial depression. With the development of our railway system about this time a new impulse was imparted to the iron industries throughout the land; for in 1847, the Yorkshire furnaces, 23 of which were in blast out of a total of 28 built, produced 67,600 tons, or an average of 3,073 tons per furnace; the make of the 433 furnaces in Great Britain, out of a total of 623 built, being 1,999,608 tons.

In the year 1851 the following list of works in operation in the northern and southern divisions of the West Riding of Yorkshire shows the resources of these establishments, cold blast being principally employed in the furnaces:—

Northern Division.			Southern Division.		
Works.	Furnaces.		Works.	Furnaces.	
	Built.	In Blast.		Built.	In Blast.
	Nos.	Nos.		Nos.	Nos.
Bowling . . .	5	3	Chapeltown . .	2	1
Bierley	4	3	Elsecar and Milton.	3	0
Farnley . . .	1	1	Holmes . . .	2	1
Low Moor . . .	3	1	Parkgate . .	1	1
New Begin . .	2	2	Thorncliffe. . .	4	2
Shelf	1	0	Worsborough Dale.	1	0
Total . .	16	10	Total. . .	13	5

The make of the furnaces in the northern division in 1851 was 25,000 tons, and in the southern division 40,000 tons, giving an aggregate of 65,000 tons or an average make per furnace of 4,333 tons.

Since the above list appeared, the works at Beeston Manor* and Thorpe Hall each commenced operations, the former in 1855 with one furnace; in 1865 the York Road and Hepworth Works, the former with two, and the latter with one furnace. In 1868 the furnaces at Ardsley, near Leeds, of the West Yorkshire Iron and Coal Company, limited, were blown in, and more recently the Atlas, Aireside, Charlton, and Tinsley furnaces.

Resuming with the production of pig iron in the West Riding of Yorkshire, the annexed summary shows the number of furnaces built and in blast in each year since 1851:—

Year.	Furnaces.		Pig Iron Made.	Year.	Furnaces.		Pig Iron Made.
	Built.	In Blast.			Built.	In Blast.	
	Nos.	Nos.	Tons.		Nos.	Nos.	Tons.
1851	29	15	65,000	1867	36	25	109,002
1854	28	21	73,444	1868	38	22	100,050
1855	32	23	90,840	1869	38	23	105,765
1856	34	23	96,200	1870	38	22	77,717
1857	36	25	117,000	1871	39	25	114,549
1858	33	24	85,936	1872	40	29½	148,636
1859	35	25	84,950	1873	40	30	151,511
1860	35	25	98,100	1874	44	31	163,856
1861	34	27	142,865	1875	50	37	267,153
1862	35	26	112,121	1876	49	34	235,451
1863	35	24	104,745	1877	48	30	229,027
1864	35	25	102,093	1878	48	29	219,547
1865	38	29	123,233	1879	49	31	218,805
1866	36	29	119,747	1880	47	33	306,560

In the last-named year the number of furnaces in operation in Great Britain, and the pig iron produced, was as follows:—

	Number of Furnaces.	Pig Iron.
		Tons.
England	378	5,752,683
Wales	76	947,550
Scotland	112½	1,049,000
Total . . .	566½	7,749,233

From the above it appears that the average production per furnace in 1848 was 2,891 tons, increased to 3,924 tons in 1860, and 9,200 tons in the year 1880, when the following works were in operation in West Yorkshire, giving the number of furnaces built and in blast, as well as the owners:—

* Works now standing, 1881.

YORKSHIRE—WEST RIDING.

No.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In Blast.
			Nos.	Nos.
1	Atlas	John Brown & Co., Limited	3	3
2	West Yorkshire, Ardsley	West Yorkshire Iron and Coal Co., Limited	5	3
3	Beeston Manor, Ardsley	A. Harding & Co.	0	0
4	Bowling, Bradford	Bowling Iron Co., Limited	6	2
5	Elsecar, Barnsley	George Dawes	4	4
6	Milton, Barnsley	" "	2	2
7	Farnley, Leeds	Farnley Iron Co., Limited	2	2
8	Holmes	Parkgate Iron Co., Limited	6	6
9	Parkgate, Rotherham			
10	Low Moor, Bradford	Hird, Dawson, & Hardy	8	5
11	Bierley			
12	Charlton, Sheffield	Charlton Iron Co.	2	0
13	Thorncliffe, Sheffield	Newton, Chambers & Co.	2	2
14	York Road, Leeds	York Road Iron and Coal Co.	2	1
15	Aireside, Leeds	Aireside Hæmatite Iron Co.	3	3
16	Tinsley, Sheffield	William Cooke & Co., Limited	2	0
		Total of West Riding	47	33

Malleable Iron Works (Mills and Forges) and Steel Works. —The manufacture of bar and other forms of iron has long been carried on in the West Riding of Yorkshire; indeed the works at Kirkstall are amongst the oldest in the kingdom, and they still prosper. A recent contribution to a scientific journal gives the following interesting account of these works:—Situated at Kirkstall Abbey, near Leeds, and from which there is no doubt but that the monks at that place many generations ago were acquainted with the manufacture of iron. The abbey was founded between the years 1147 and 1153 by monks of the Cistercian Order, whose house was not dissolved till the year 1540, its revenue at that time being assessed at from £8,000 to £10,000 per annum. In digging some foundations there was the most complete evidence met with, that iron had been made on the ground some hundreds of years ago; and there is an old water-wheel that used to work the helves upwards of two hundred years ago.

The works as they are now, were established in the year 1779, by the ancestors of the present owners, the Messrs. Butler, and are famous for the production of railway tyres, axles, and bars, and for hydraulic presses, for pressing iron and steel, one having

been made on the Haswell system, capable of exerting a pressure of something like 1,400 or 1,500 tons. The works are also known in connection with machines for straightening and planishing round bars; as well as steam-hammers on Naylor's system. The works of the Kirkstall Forge, it may be stated, cover an area of nearly fourteen acres, and when in full operation give employment to nearly one thousand hands. An interesting fact is stated by Mr. Butler of these works, that the Staffordshire iron trade in some measure sprang from them, inasmuch as two lads went from Kirkstall forge into Staffordshire, and there set up a small establishment, where they made bullet-iron. These lads it appears were the Thorneycrofts, a name so well known in connection with the Staffordshire iron trade. Again, it is stated of the firm of Messrs. Bolckow and Vaughan, that the father of the latter turned rolls at Kirkstall forge before going farther north. The Works and the Abbey are amongst the most interesting objects to be seen near Leeds, and showing the antiquity of the works in connection with the ruins, there is a cast-iron mullion to be seen in one of the windows, which must have been made centuries ago. At the present time there are in the immediate vicinity of Leeds and Bradford 14 extensive iron works, and in the districts of Sheffield and Rotherham 16 works, with an aggregate of 497 puddling furnaces and 129 rolling mills, of which the following is a list:—

Leeds and Bradford District.

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Normanton	Normanton Iron & Steel Co.	Normanton	..	..
2	Hunslet Forge	Coghlan & Dury	Leeds	25	5
3	Clarence	Taylor, Brothers, & Co.	"	17	5
4	Farnley	Farnley Iron Co.	"	16	5
5	Kirkstall Forge	The Kirkstall Forge Co.	"	28	5
6	Leeds	S. T. Cooper & Co.	"	13	6
7	Monk Bridge	Monk Bridge Iron Co.	"	27	6
8	Thornhill	E. T. Ingham	"	9	3
9	Perseverance	J. Whitham & Son	"	..	..
10	Bowling	Bowling Iron Co., Lim.	Bradford	20	4
11	Low Moor	Hird, Dawson & Hardy	"	38	8
12	Thornton Road	Perkins, Son, & Barrett	"	7	2
13	Calder Vale	Samuel Whitham	Wakefield	..	..
14	Horbury Junction	Horbury Junction Iron Co., Limited	"	13	2
	Total of District			213	51

SHEFFIELD AND ROTHERHAM DISTRICT.

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Atlas Steel and Iron (Swinton).	John Brown & Co., Lim.	Sheffield	60	19
2	Cyclops	Ch. Cammell & Co., Lim.	"	61	9
3	Gremisthorpe	" "	"	0	1
4	Yorkshire Steel and Iron Works, Penistone	" "	"	0	4
5	Millsands	Sheffield Forge and Rolling Mills Co., Lim.	"	0	8
6	Wortley	Thomas Andrews & Co.	"	16	4
7	Midland	Midland Iron Co., Lim.	Rotherham	34	4
8	Phœnix Bessemer Steel Works	Steel, Tozer, and Hampton, Limited	Sheffield	0	4
9	Park Gate	Park Gate Iron Co., Lim.	"	50	6
10	Northfield	Neill, Johnson & Edgar	"	..	..
11	Elsecar	George Dawes	Barnsley	46	7
12	Milton	" "	"		
13	Stockbridge	Samuel Fox & Co., Lim.	Sheffield	4	3
14	Kelham	Kelham Rolling Mills Co.	"	..	..
15	Tinsley Iron and Steel	William Cooke & Co., Lim.	"	26	5
16	Charlton	Charlton Iron Works Co.	"	..	..
	Total of District			297	74

Coincident with the development of our railway system Sheffield more especially became the seat of many new branches of iron and steel manufacture, such as rails, tyres, axles, wheels, girders, railway waggons, and all forms of forgings and castings for fixed and rolling stock, armour plates, &c. In this neighbourhood are situated the gigantic establishments, the Atlas and Cyclops, which have for years exercised such an important influence in connection with the national defences of the empire. The Atlas works commenced operations about the year 1857, under the auspices of Messrs. John Brown and Co., who initiated the manufacture of those vast plates of iron which have in modern times contributed to the armoured covering of our ironclads, besides other heavy iron and steel works. A few years later the Cyclops steel and iron works were founded by Messrs. Charles Cammell and Co., and these two firms stand unrivalled in the resisting power their armour plates offer to the heaviest ordnance directed against them. The Messrs. Cammell and Co. have other works on an extensive scale at Gremisthorpe and Penistone, at the former of which the manufacture of cast steel is carried on, also the manufacture of steel by the Siemens Martin process, while at the Penistone Works, known as the Yorkshire Steel and Iron Works, steel is made by the Bessemer process, which has rapidly extended of late years in the neigh-

bourhood of Sheffield and Rotherham. The following is a list of those important establishments, with the names of the firms and the number and capacity of the convertors as they stood in the beginning of 1881:—

Works.	Situation.	Firms.	Convertors. No.	Capacity. Tons. Cwt.
Atlas	Sheffield	John Brown & Co., Limited	4 2	7 10 10 0
Bessemer	"	Henry Bessemer & Co., Limited	2 2	3 0 5 0
Attercliffe	"	Brown, Baily, & Dixon, Limited	2 4	4 0 8 0
Cyclops	"	Charles Cammell & Co., Limited	4	4 0
Phoenix	"	Steel, Tozer, & Hampton, Limited	2 2 2	8 0 6 0 2 0
Stockbridge	"	Samuel Fox & Co.	2	5 0
Yorkshire	"	Charles Cammell & Co., Limited	2 2	5 0 7 0

Coal and Iron Ore used in Manufacture.—In the year 1840, according to Mr. Porter, F.R.S.,* the quantity of pig iron made in Yorkshire was 56,000 tons, consuming 306,500 tons of coal in its manufacture, being an average of near five and a-half tons to each ton of pig iron made. In the year 1873, Mr. Joseph Wilcock,† chief engineer of Bowling iron works, states the following as the relative quantities of materials employed for producing one ton of "Bowling pig iron:"—

MATERIALS.	Tons.	Cwts.	Qrs.	Lbs.
Raw ore	3	3	3	27
Calcined ore	2	7	1	26
Limestone	0	18	2	12
Coke	2	5	0	9

The raw ore containing 32 per cent. of metallic iron, increased to 42 per cent. by calcination. The coal employed is known to yield on the average 60 per cent. of coke, which would, converting the above named quantity into coal, give an average of 75 cwts. to each ton of pig iron made.

Since the year 1872 the quantities of coal and iron ore used in

* "Progress of the Nation," G. R. Porter, F.R.S.

† Paper read at Bradford Meeting of British Association for the Advancement of Science.

manufacture were as follows; the pig iron made also appears. The increased consumption of coal in the West Riding furnaces it will be remembered is due to the employment of cold blast, still extensively used in the district:—

Year.	Pig Iron.	Coal Used.	Ore Used.
	Tons.	Tons.	Tons.
1872	148,636	443,654	490,000
1873	151,511	493,976	499,000
1874	163,856	549,363	525,000
1875	267,153	695,557	825,000
1876	235,451	555,230	730,000
1877	229,027	635,712	712,500
1878	219,547	612,504	695,000
1879	218,805	556,775	692,000
1880	306,560	769,519	945,000

Taking the years 1872 and 1873 the average consumption of coal to each ton of pig iron made was 65 cwts., the average of the iron ore (uncalcined) being about 66 cwts. The economy in the use of coal is observable here as in other districts; thus, in 1877 the average was 55½ cwts.; in 1878 increased to 56 cwts.; while in the past year it did not exceed 50 cwts. throughout the district; in some of the works however a higher average was consumed. In the consumption of iron ore the proportion is fairly maintained, the returns not exhibiting the same fluctuations from year to year, as with the coal, due to the fact that as regards the iron ore the returns give the raw material while the coal used is occasionally recorded as coke, its equivalent in all cases being subsequently ascertained.

CHAPTER III.

YORKSHIRE—NORTH-RIDING (CLEVELAND DISTRICT) IRON INDUSTRIES.

Geology of—Analyses, production and average prices of Ore—Output of the more important Mines—Magnetic Iron ore of Rosedale—Mines in Cleveland District—Ironstone Mining—Distribution of Ironstone—Population employed in Iron Mining—Barrow's Views on the Mineral Resources of the district—Pig Iron Manufacture—Early history, production, distribution, and average prices of Cleveland pig—Coal and Ironstone used in manufacture—Malleable Iron and Steel Works—Production and average prices of rails, plates, bars, and angles—The Thomas Gilchrist process of Steel manufacture.

Yorkshire, North Riding (Cleveland District).—The existence of an iron ore on the North-Eastern coast of Yorkshire appears to have been long known; indeed the constant discovery of iron slag on the hills of Cleveland shows clearly that ores were worked in a remote antiquity. About thirty years since some local iron-masters began to employ the Cleveland ore, to supplement the supply of ores to their furnaces. It answered well, and when the increased demand for iron ore stimulated inquiry, it was found that the Cleveland Hills were full of iron. Then began that remarkable development of the district which can scarcely find a parallel in the history of any British industry. The area of the Cleveland Hills containing the deposits of iron ores, extend on the northern escarpment from Ormesby, near Middlesborough, to the coast, and southernly to the Eskdale and Rosedale valleys; the workable portion of the iron ore being found most fully developed in the north-west portion of the area, diminishing both in the thickness of the beds and the quality of the ore in the south and eastern part of the area.

The main ironstone seam of Cleveland occurs at the top of the "Middle Lias," or marlstone rock, and consists of a bed of ironstone with beds of shale above and below; a lower seam, known as the "Bottom Seam," of fair quality also occurs. This seam is comparatively unimportant in the area of greatest

development of the main seam, but acquires considerable importance in the neighbourhood of Grosmont, south-east of Whitby, where it contrasts favourably with that bed. At Eston, near Middlesborough, on its northern outcrop, the main seam attains its greatest thickness, varying from 12 to 17 feet. Throughout the main seam occurs the well known (Pecten æquivalvis), from which it is called Pecten bed.

The same strata in the south, in the neighbourhood of Grosmont, attain a thickness of 12 feet of ironstone, but with shaly partings of nearly 30 feet in thickness, the ironstone thinning out towards the south, where at Felixkirk, three miles north-east of Thirsk, it has been proved to exist in beds of six and seven inches, with shale partings of three feet.

The main seam at Upleatham is 13 feet in thickness and undivided; it however exhibits various appearances throughout the mass, not as separate bands, but one structure graduating into the other. In the Yorkshire Lias the following detailed section of the ironstone series at Upleatham is given, which may be generally regarded as a standard of reference.*

Top Block or Roof, 3 feet thick, consisting of:—

1. A brownish compact argillaceous ironstone with diffused oolitic green grains.

2. Rather more oolitic than No. 1, the argillaceous matter more diffused; small phosphatic nodular particles scattered through the mass.

3. Similar to No. 1 but more oolitic.

4. Sulphur bands.—A rock composed of oolitic grains, consisting chiefly of iron pyrites. An analysis gives 30·25 per cent. of sulphur—corresponding to 56·71 per cent. of bisulphide of iron.

   (This band was formerly worked at Eston, and applied at the Chemical Works at Washington, and subsequently at Middlesborough as a substitute for ordinary pyrites. It generally separates in loose ground from the underlying main block in the process of mining, and when sound makes an excellent roof; but its extreme liability to disintegrate on the action of moist air necessitates caution in placing reliance upon it.)

Workable Main Seam, 10 feet thick, consisting of:—

5. Top part of main block.—A greyish to bluish stone colour, not uniform, somewhat compact, with pebble-like lumps of an earthy substance of a much lighter colour than the ore and zinc blende, occupying centres of the more argillaceous parts, very fossiliferous.

* "The Yorkshire Lias." Tate and Blake, p. 119.

6. Middle part of main block, about 5 feet thick.—A light blue stone, oolitic in structure, but the grains of variable size, with crystals of carbonate of iron and carbonate of lime. The dissolution of the crystals having left cavities in the stone, imparts a cinder-like aspect to this part of the seam by which it may easily be recognised.

7. Lower part of main block.—A greenish blue stone, rather close in texture, and of a finely oolitic structure. A strong parting separates it from the underlying stratum near the outcrop.

8. Bottom block of main seam, 2 feet thick.—A compact earthy splintery rock of a dark green colour, partaking of the character of a hard mudstone, and perfectly devoid of oolitic structure, which prevails in all the higher parts of the seam.

   (Analysis shows it to be rich in alumina and silica, but the percentage of iron does not fall much below the average of that of the main block; it is however rejected by most iron smelters. It is called by the miners "black hard.")

9. A bed of shale 1 foot thick, which underlies and is called from the prevalence of Rhynchonellæ, which are occasionally aggregated in stony lumps, the "cockle bed." It yields as much as 21 per cent. of metallic iron, the other chief matter being alumina, silica, and lime.

10. Hard shale 4 feet.

11. Bottom seam of ironstone.—A dense blue clay ironstone, speckled with white and green—2 ft. 8 in. Fossils not abundant. Pecten Aequitalvis and others.

12. Shale.

The main seam, near Guisborough, at the Chaloner Mines, has a thickness of 13 feet; at the Normanby Mines, near Middlesborough, it is 11 feet; while at the Whitecliffe and the Liverton Mines, near Loftus, it is 9 feet 6 inches, with a shale parting in the middle. Again, at Ailesbury, near Swainby, it varies from 5 feet 6 inches to 6 feet 6 inches.

Below the Middle Lias, at the top of which is the ironstone main seam above referred to, succeeds the Lower Lias, and immediately above occur the shales of the Upper Lias, in which exist the beds of alum shale and jet, which have given rise to these important industries, of which Whitby may be regarded as the centre.

Above the Upper Lias, and situated at the base of the sandy estuarine beds of the Inferior Oolite, occurs the top seam of ironstone, known as the "Dogger bed," and which has, and still is, acquiring much importance from its highly magnetic character, in the Rosedale Abbey Mines, where the seam is upwards of

20 feet thick. This top seam is regarded as the equivalent of the Northampton sand, and yields a much higher percentage of metallic iron than that of the main seam of Cleveland. The Cleveland district has an area of not less than 500 square miles, and reliable authorities affirm that every acre of this vast area contains ironstone, though it remains to be proved what proportion is workable. The system of working is both by drifts from the outcrop and by shafts, which are sunk in places dependant upon the position of the ironstone, which is usually wrought by the bord and pillar system.

Analyses of the Ironstone.—The Cleveland ore of Eston, examined in Dr. Percy's laboratory in the Royal School of Mines by Mr. A. Dick, is thus referred to.* "Description: chiefly a carbonate of protoxide of iron; lustre, earthy; colour, greenish grey; streak, similar; fracture, uneven; showing here and there small cavities, some of which are filled with carbonate of lime. Throughout the ore are diffused irregularly a multitude of small oolitic concretions, together with small pieces of an earthy substance resembling the ore but lighter in colour. When a mass of the ore is digested in hydrochloric acid till all carbonates and soluble silicates are dissolved, there remains a residue having the form of the original mass of ore. It is extremely light, and falls to powder unless very carefully handled. It contains the oolitic concretions or else skeletons of them, which dissolve completely in dilute caustic potash, showing them to be silica in a soluble state. Under the microscope some of them are seen to have a central nucleus of dark colour and irregular shape, but none of them present any indication of organic structure or radiated crystallisation."

"If the residue, after having been digested in caustic potash, be washed by decantation, there remains a small number of microscopic crystals; some of these, which are white, are quartz, and others, which are black and acutely pyramidal, consist chiefly of titanic acid. Professor Miller, of Cambridge, succeeded in measuring some of the angles of the crystals containing titanic acid, and found that they correspond to similar angles in anatase. The green colour of the ore seems to be due to a silicate con-

* Memoirs of the Geological Survey, "Iron Ores of Great Britain," Part I., p. 95 (out of print).

taining peroxide and protoxide of iron, but this could not be exactly determined, because it was not found possible to dissolve out the carbonates without at the same time acting upon the silicate of iron. The constituents are as follows:—

RESULTS TABULATED.—ORE DRIED AT 100° C.

Protoxide of iron	39·92
Peroxide of iron	3·60
Protoxide of manganese	0·95
Alumina	7·86
Lime	7·44
Magnesia	3·82
Potash	0·27
Carbonic acid	22·85
Phosphoric acid	1·86
Silica soluble in hydrochloric acid	7·12
Sulphuric acid	trace.
Bisulphide of iron	0·11
Water in combination	2·97
Organic matter	trace.
Insoluble residue (of which 0·98 is soluble in dilute caustic potash) and consists chiefly of oolitic concretions	1·64
	100·41
Iron, total amount	33·62

INSOLUBLE RESIDUE.

Silica	1·50
Alumina, with a trace of peroxide of iron	0·10
Titanic acid about	0·03
Lime	trace.
	1·63

A note appended to this analysis states that "No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of about 1,200 grains of ore was detected."

Other analyses of the main seam of ironstone worked at the Normanby mines of Messrs. Bell Brothers, and situated to the south-east of Eston, and at the Upleatham mines of Messrs. J. W. Pease and Co., situated about three miles to the north-east of Guisborough, where it is found under the most favourable conditions as regards richness of metal, give the following constituents, the metallic iron contained in the Normanby ore amounting to 31·42 per cent., and the Upleatham ore yielding 31·97 per cent.:—

RESULTS TABULATED.

Constituents.	Normanby.	Upleatham.
Protoxide of iron	38·06	37·07
Peroxide of iron	2·60	4·48
Protoxide of manganese . .	0·74	...
Alumina	5·92	12·37
Lime	7·77	4·67
Magnesia	4·16	2·69
Carbonic acid	22·00	23·46
Silica	10·36	10·63
Sulphur	0·14	...
Phosphoric acid	1·07	1·17
Water	4·45	3·36
	97·27	99·90

The iron ore obtained from the Belmont Mines, near Guisborough, is very similar in character to the preceding, but from its greater density and compactness it would seem to have been derived from a lower measure. The ore employed at the South Bank Furnaces, Middlesborough-on-Tees, is described as: "A dull green, earthy, carbonate of iron, with silicate, containing abundance of small oolitic concretions, a few belemnite stems, and other fossil remains. Small crystals of quartz of zinc blende, and apparently also of titanite, were found in the specimen examined."*

The composition of these ores is represented by the following analyses:—

RESULTS TABULATED.

Constituents.	Belmont.	South Bank.
Protoxide of iron	39·00	43·02
Peroxide of manganese . .	3·50	2·86
Protoxide of iron	1·30	0·40
Alumina	7·46	5·87
Lime	7·44	5·14
Magnesia	3·82	5·21
Carbonic acid	23·06	25·50
Phosphoric acid	1·60	1·81
Silica (soluble)	9·46	7·12
Silica as quartz		0·05
Titanic acid	...	traces.
Sulphide of zinc	...	
Water hygroscopic	3·66	0·34
Water in combination . . .		3·14
Organic matter	...	0·15
	100·30	100·61

* "Papers: Cast-Iron Experiments," 1858, pp. 40 and 34.

The metallic iron contained in the Belmont ore amounts to 32·78 per cent., and in the Cleveland ore, employed in the South Bank Ironworks, then belonging to Messrs. Samuelson & Co., 35·46 per cent.; it being observed of the latter ore that it does not contain any appreciable amount of sulphur nor of heavy metals.

The ironstone raised at Hutton Low Cross, near Guisborough, was examined by Mr. Crowder. The samples selected of the ore from three parts of the bed, are described: (*a*) as grey, hard, compact and heavy, and with very few oolitic grains; (*b* and *c*), as a softer stone, uneven in fracture, and containing many oolitic grains.

RESULTS TABULATED.

Constituents.	*a.*	*b.*	*c.*
Protoxide of iron	35·55	35·75	40·86
Sesquioxide	1·70	1·80	4·25
Alumina	3·79	4·95	3·44
Lime	4·20	7·39	3·80
Magnesia	1·12	2·98	3·70
Sulphuric acid	trace.	0·07	0·30
Silica	20·90	15·65	7·20
Carbonic acid	25·18	23·47	32·50
Phosphoric acid	2·66	5·05	0·96
Bisulphide of iron	trace.	trace.	1·60
Water	4·90	4·89	1·45
	100·00	102·00	100·06
Iron, total amount	28·84	27·45	34·75

An average analysis of the same ironstone, by Richardson, gives the constituents as under:—

RESULTS TABULATED.

Peroxide of iron	42·08
Protoxide of iron	0·68
Alumina	10·40
Lime	5·48
Magnesia	1·84
Silica	14·00
Sulphur	...
Phosphoric acid	...
Carbonic acid } Water }	24·22
	98·70
Iron, total amount	33·09

Mr. John Pattinson, of the Clarence Ironworks, gives the following as the results of his examination of the Cleveland raw ironstone, and of the same ore after calcination: *—

Constituents.	Raw Stone.	Calcined Stone.
Protoxide of iron . . .	34·04	...
Peroxide of iron	3·74	58·30
Protoxide of manganese . .	0·38	0·53
Alumina	9·32	13·07
Lime	5·08	7·12
Magnesia	3·65	5·12
Carbonic acid	20·09	...
Silica	10·04	14·08
Sulphur	0·13	0·18
Phosphoric acid	1·13	1·59
Organic matter . . .	0·36	...
Combined water	2·53	...
Water expelled by drying at 212°	9·50	...
	99·99	99·99

The amount of metallic iron in the raw stone giving 29·09 per cent.; concentrated in the calcined stone to the extent of 40·81 per cent., the loss by calcination being 28·71 per cent.

The magnetic ironstone of Rosedale has been wrought in two localities, namely, at Rosedale Abbey, East and West Mines, and at Sheriffs' Mines. The first two analyses are those of Mr. W. Crowder and Mr. J. Pattinson, and the third was made in the Clarence Laboratory of Messrs. Bell Brothers. The Rosedale Abbey stone is chiefly smelted at the Ferry Hill Ironworks, Durham, and to some extent as a mixture at other works. In quality the iron is stated to be like that which is obtained from the main beds of ironstone in Cleveland.

The Ingleby stone occurring among the oolitic rocks being thin and expensive to work has long since been abandoned. Mr. I. L. Bell states a few hundred tons were smelted without admixture at the Clarence Works. "The content of iron was verified as being superior to the ordinary Cleveland main seam, but the metal in quality did not differ from the usual make of the district."

* Transactions of South Wales Institute of Mining Engineers, vol. vi. p. 285.

RESULTS TABULATED.

Constituents.	ROSEDALE ABBEY.		Ingleby Stone.
	Black Stone.	Blue Stone.	
Protoxide of iron	...	33·85	41·14
Peroxide of iron	64·90	32·67	7·07
Peroxide of manganese . .	...	0·69	0·94
Alumina	9·25	3·15	4·71
Lime	3·53	2·86	3·32
Potash	...	...	0·20
Magnesia	0·99	1·59	3·34
Silica	5·70	6·95	7·37
Loss by heat	16·15	...	...
Carbonic acid	...	10·36	26·00
Phosphoric acid	...	1·41	1·36
Bisulphide of iron . . .	...	0·03	0·08
Water	...	4·60	4·24
	100·52	98·16	99·77

The metallic iron contained in these ores amounts respectively to 45·43 per cent., 49·20 per cent., and 36·95 per cent. The Rosedale ore, employed some years since at the works of the Consett Iron Company in a calcined state, gave very satisfactory results: 632 tons 8 cwts. of calcined stone produced 344 tons 13 cwts. of pig-iron; and at the Park Gate Ironworks, near Rotherham, the raw stone was found to yield 45 per cent. of metallic iron.

The Pecten and Avicula beds of ironstone are worked by the Messrs. John and Thomas Bagnall, also the Dogger bed, at Grosmont. The two first-named beds are well developed at Grosmont Hall, about six miles south-west of Whitby, and one mile south-east of Eston, in the following section:—

SUCCESSION OF BEDS.*

	Ft.	In.
1. Shale and bands and doggers of ferro-argillaceous stone	27	2
2. "Main" or "Pecten Seam" of Ironstone	4	6
3. Shale and doggers	31	0
4. "Bottom" or "Avicula Seam"	3	9
Total thickness	66	5

These ironstones, examined by Mr. Charles Tookey, in Dr. Percy's laboratory, exhibit the following constituents: †—

* "The Yorkshire Lias," Tate and Blake, p. 147.

† Dr. Percy's Metallurgy, "Iron and Steel," p. 223.

RESULTS TABULATED.

Constituents.	Avicula Bed.	Pecten Bed.	Dogger Bed. a.	Dogger Bed. b.	Dogger Bed. c.
Protoxide of iron	33·17	34·98	32·78	22·30	40·77
Protoxide of manganese	0·50	0·48	0·45	0·50	0·67
Alumina	3·92	3·20	1·18	2·10	1·32
Lime	11·90	11·96	6·44	11·80	4·08
Magnesia	4·52	4·51	4·58	3·96	5·34
Carbonic acid	28·00	29·20	26·13	24·40	31·80
Phosphoric acid	0·48	1·30	0·19	0·30	0·06
Water	3·65	3·30	2·80	3·20	2·70
Ignited insoluble solution	13·22	10·04	24·10	30·96	12·36
	99·36	98·97	98·65	99·52	99·10
Ignited Insoluble Solution.					
Silica	9·42	8·00	18·12	23·10	8·80
Iron, total amount	25·80	27·21	25·50	17·34	31·71

In the following table will be found some of the more important localities in Cleveland in which ironstone is raised, and which has been examined, together with the name of the analyst and the amount of metallic iron :—

Name of Mine.	Analyst.	Metallic Iron per cent.
Eston	Mr. A. Dick	33·62
Normanby	Mr. I. L. Bell	31·42
Upleatham	,,	31·97
Belmont	Professor F. A. Abel	32·78
South Bank	,,	35·46
Hutton Low Cross (a.)	Mr. W. Crowder	28·84
,, ,, (b.)	,,	27·45
,, ,, (c.)	,,	34·75
Hutton Low Cross	Mr. Richardson	33·09
Cleveland (Raw)	Mr. John Pattinson	29·09
,, (Calcined)	,,	40·81
Rosedale (Black Stone)	Mr. I. Lowthian Bell	45·43
,, (Blue Stone)	,,	49·20
Ingleby Stone	,,	36·95
Grosmont (Avicula Bed)	Mr. Charles Tookey	25·80
,, (Pecten Bed)	,,	27·21
Dogger Bed (a.)	,,	25·50
,, (b.)	,,	17·34
,, (c.)	,,	31·71
Spa Wood	Thomas Allison	31·00
Kirkham	...	34·00
Sleight's Bridge	Mr. W. Crowder	29·83
Grosmont Tunnel	,,	28·60

Production of Ironstone.—Originally it appears that the ironstone of Cleveland was collected on the beach, and this was done from an early date. Mr. I. Lowthian Bell mentions * that for the Whitehill Furnace, built in 1745 and abandoned before the end of the last century, ironstone was gathered in Robin Hood's Bay and conveyed by water to Picktree-on-the-Wear, near Chester-le-Street, and carted from that place to the works. Soon after the year 1800 the Tyne Iron Company obtained ironstone in a similar way from the beach between Scarborough and Saltburn; and according to Bewick, in his work on the Cleveland ironstone, the firm commenced between the years 1815 and 1820 to tear up the stone from its bed at different parts of the coast. It is stated that the discovery of the ironstone was due to a Mr. Wilson, then a partner in the Tyne Iron Company's Works, who pointed out its position at Grosmont, about five miles from Whitby, about the year 1836.

The seam being 4½ feet thick was cheaply worked, the stone sent down the railway and shipped at all seasons for the Tyne, where it would at that time cost about 9*s*. per ton. It is probable that ultimately as much as from 80,000 to 100,000 tons of it were annually smelted in the North-country furnaces.

The Whitby Stone Company commenced operations on the Grosmont Seam, known as the "Pecten Seam," and in May, 1836, sent their first cargo of 55 tons to the Birtley Ironworks. A second quantity was subsequently received by the same company but rejected; however the stone was again tried, and finally permanent contracts were entered into in 1838. About the same time this ironstone was also wrought at two villages, Kettleness and Staithes, the one about five and the other ten miles nearer the mouth of the Tees than Whitby; and about the year 1842 a blast furnace was erected at Walker, being the first specially constructed for smelting what was then known as Whitby or Yorkshire stone.

In the meantime, that is in the year 1840, Messrs. Bolckow & Vaughan established themselves as bar-iron manufacturers at the town of Middlesborough, and five or six years afterward, like others elsewhere before them, mistaken in the extent of local deposits of ironstone, were induced to erect four blast furnaces

* "Manufacture of Iron, Tyne, Wear, and Tees:" British Association Report, 1863.

on the South Durham Coal-field at Witton Park, about 25 miles west of their works at Middlesborough. A very short time sufficed to dispel the illusion, and about the year 1846 they also became dependent upon Whitby for their supplies of ore. The mineral was conveyed thence by vessel to their works on the Tees, unloaded, sent up by rail to Witton Park, and brought back to Middlesborough in the form of pig-iron; although a bed of stone identical with that from which it was worked lay within four miles of the wharf where they were unloading the sea-borne cargoes from Whitby. Previous to the ironstone being worked from the seams at Kettleness and Staithes, that which had been gathered on the beach consisted chiefly of water-worn masses. So far back as 1822 the series of beds of ironstone at Boulby were estimated by Young and Bird to have an aggregate thickness of 15 feet; but the main deposit itself appears to have been mistaken by those writers for limestone. Guided probably by detached masses which had fallen from the cliff along which it runs, the Great Cleveland ironstone was discovered about 1849 by John Roseby, a practical miner, in the valley of Skinningrove.

In September, 1850, the first ton of ironstone was worked from Eston Hill for trial at the Witton Park works. Previous to this the Valley of the Esk, and, to a small extent, the coast, furnished the necessary ironstone. Subsequently the quantity raised on the coast was increased a little in consequence of the seam near Skinningrove being recognised as containing more iron.

Commencing with the year 1854, when returns of production first appear, 650,000 tons of ironstone were raised in the Cleveland district, increased to 865,300 tons in 1855, and 1,148,488 tons in 1856. Additional quantities were obtained in each of the same years from the Esk Valley, and the coast, amounting in 1855 to 105,000 tons, and in 1856 to 98,124 tons; bringing up the total production of Cleveland in 1855 to 970,300 tons, and in 1856 to 1,246,612 tons. The detailed production of the mines for the year 1856 are thus given by Mr. John Marley in his paper.* This memoir contains much important matter, and gives an account of the ironworks then in operation, and the several mines in Cleveland from whence the works received their supply of ironstone:—

* "Memoir on Cleveland Ironstone, &c.," 1857.

NAMES OF MINES.	QUANTITIES.
Eston	568,156 tons.
Hutton Lowcrop or Codhill	217,253 ,,
Upleatham	171,360 ,,
Normanby	131,575 ,,
Belmont or Belmont Bank	73,164 ,,
Rosedale Cliff and Staithes	23,500 ,,
South of Staithes	12,500 ,,
Raithwaite	5,916 ,,
Sleight's Bridge	11,250 ,,
Eskdale Iron Company	5,438 ,,
Whitby Stone Company	22,500 ,,
"The Quarry," Rosedale	4,000 ,,
Total	1,246,612

In the following year (1857) seven new mines were in operation, increasing the production in that year to 1,414,155 tons, of which 7,500 tons was magnetic ore obtained from the deposits at Rosedale Abbey. In 1857 and subsequent years the production of the Cleveland Hills will be seen in the annexed table, with the number of mines producing ironstone in each year:—

Year.	Number of Mines.	Ironstone Raised.	Year.	Number of Mines.	Ironstone Raised.
		Tons.			Tons.
1857	17	1,414,155	1869	16	3,094,678
1858	17	1,367,395	1870	17	4,072,888
1859	15	1,520,342	1871	21	4,581,901
1860	17	1,471,319	1872	31	4,974,950
1861	17	1,242,514	1873	35	5,617,014
1862	16	1,689,966	1874	35	5,614,322
1863	13	2,078,806	1875	39	6,121,794
1864	14	2,401,890	1876	36	6,562,000
1865	20	2,762,359	1877	33	6,284,545
1866	19	2,809,061	1878	29	5,605,639
1867	17	2,739,039	1879	29	4,750,000
1868	15	2,785,307	1880	29	6,486,654

Considerable difficulty stands in the way of getting the exact value of the ironstone raised in Cleveland, chief among them being the large proportion which is consumed in the furnaces of the mine owners, and in regard to which there is therefore no sale, and the further large proportion which is to be delivered under contracts made many years since and having many years to run, at prices which are no guide to the existing values. Ironstone was selling in Cleveland in 1860 at 6*s*. per ton, ten years later the average price was 5*s*., at which price it continued during 1871, rising in the following year to 7*s*. 6*d*. per ton, the highest average price ever reached. During 1874 it averaged 6*s*. per ton, and since that date has continued to fall.

In the year 1875 the question of value was carefully considered by "The Mine Owners' Association," and the average price given was 4*s*. per ton net at the mines. Again, in 1876, the average price was given as varying from 3*s*. 4*d*. to 3*s*. 9*d*. per ton; and in 1877, from 3*s*. to 3*s*. 6*d*. per ton; the same prices existing in 1878. When, in 1877, it became difficult to work the mines to advantage, and this, with a decreasing demand, led to the closing of many of them, prices again fell, and in 1879 the average prices given were from 2*s*. 9*d*. to 3*s*. 3*d*. per ton, increased in 1880 to from 3*s*. 3*d*. to 3*s*. 9*d*. per ton, these prices having been adopted as the nearest approach to the correct value that could be arrived at.

The detailed production of the mines in Cleveland in the year 1880 is given in the following statement, showing an increase over the previous year of 1,736,654 tons:—

No.	Names of Mines.	Quantities. Tons.	Cwts.	Value. £	*s.*	*d.*
1	Ailesbury (Swainley) . .	66,042	0			
2	Belmont (Guisborough) . .	110,148	15			
3	Boosbeck ,, . .	486,695	12			
4	Brotton (Saltburn) . . .	510,302	4			
5	Chaloner (Guisborough .	*260,000	0			
6	Cragg's Hall ,, . . .	257,491	18			
7	Carlin How ,, . . .	115,465	12			
8	Cliff ,, . . .	58,332	10			
9	Eston (Middlesborough) .	1,037,654	0			
10	Grosmont (York) . . .	134,671	0			
11	Huntcliffe (Saltburn) . .	173,157	7			
12	Lane Head (Rosedale) . .	3,109	16			
13	Lingdale (Guisborough) .	98,531	6			
14	Lofthouse (Loftus) . . .	584,049	16			
15	Long Acres (Saltburn) . .	240,315	0	1,135,164	12	0
16	Normanby (Middlesborough)	160,405	6			
17	Ormesby ,, .	144,609	12			
18	Kirkleatham (Redcar) . .	92,615	7			
19	Park Pit	393,787	6			
20	Port Mulgrave and Grinkle .	170,576	0			
21	Rosedale West . . .	6,079	0			
22	Slapewath (Guisborough) .	47,114	18			
23	Spa ,, .	108,055	19			
24	Spa Wood ,, . .	15,271	9			
25	Skelton (Marske) . . .	117,182	19			
26	Skelton North (Saltburn) .	247,735	3			
27	Stanghow (Saltburn) . .	29,541	16			
28	Upleatham (Marske) . .	794,886	15			
29	Sundry Mines	22,826	12			
	Total of North Riding of Yorkshire . . .	6,486,654	18	1,135,164	12	0

* Estimated.

As showing the extent of production in some of the mines wrought for a quarter of a century, the following have been selected, viz., Eston, Normanby and Upleatham, giving the total output in each year since 1856:—

Year.	Eston.	Normanby.	Upleatham.
	Tons.	Tons.	Tons.
1856	568,156	131,575	171,360
1857	562,473	159,898	171,366
1858	507,265	166,785	190,306
1859	638,620	204,260	265,524
1860	613,391	186,152	391,410
1861	565,285	83,471	288,191
1862	608,420	235,758*	433,139
1863	633,206	140,348	573,613
1864	639,404	148,417	689,940
1865	685,980	139,417	719,998
1866	710,156	147,213	753,022
1867	665,975	†	840,577
1868	715,248	169,769	872,335
1869	761,594	†	892,771
1870	831,787	215,615	959,648
1871	532,821	256,023	1,034,530
1872	†	254,272	811,579
1873	705,228	221,485	711,360
1874	569,240	224,821	585,416
1875	571,621	238,107	640,905
1876	581,978	199,254	662,200
1877	592,478	238,152	613,744
1878	557,982	228,430	732,139
1879	540,749	239,098	714,075
1880	1,037,654	160,405	794,886

The mines above referred to belong respectively to Messrs. Bolckow & Vaughan, Messrs. J. W. Pease & Co., and Messrs. Bell Brothers, who also possess many other mines in the district.

During the past few years the mines in the neighbourhood of Saltburn-by-the-Sea and Guisborough have produced ironstone in the following quantities:—

SALTBURN-BY-THE-SEA.

Year.	Brotton.	Cragg's Hall.	Huntcliffe.	Skelton.	North Skelton.	South Skelton.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1872	392,783	196,508	180,473	...	166,419	4,034
1873	375,334	169,507	173,221	157,755	165,279	133,492
1874	337,783	198,000	184,425	158,636	157,755	182,253
1875	384,436	217,539	145,487	148,776	137,133	314,237
1876	403,309	179,639	121,613	206,003	278,097	437,872
1877	458,163	175,211	166,326	20,549	297,193	379,112
1878	481,631	171,992	190,716	...	191,732	236,582
1879	410,334	167,675	198,895	10,029	201,843	133,403
1880	510,302	257,492	173,157	...	247,735	117,182

* Including Skelton. † Included in other returns.

Those named around Guisborough being as follows, in each of the years since 1872 :—

Year.	Boosbeck.	Chaloner.	Slapewath.	Spa.	Spa Wood.	Belmont.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1872	...	15,831	47,547	...	...	181,068
1873	4,785	100,513	52,000	...	...	134,965
1874	133,316	150,393	25,000	...	...	172,805
1875	222,637	207,694	51,368	111,861	83,536	161,185
1876	237,978	207,894	73,298	91,270	69,301	117,000
1877	265,870	234,995	78,001	75,662	45,303	57,301
1878	288,210	322,332	80,542	60,825	83,536	8,967
1879	318,659	261,392	26,236	64,556	3,698	34,352
1880	486,695	260,000	47,119	108,056	15,271	110,148

Other mines have exceeded the output of many of the above, notably the Kirkleatham at Redcar, the Loftus at Lofthouse, and the Liverton at the same place.

The Rosedale Abbey Estate, which has acquired some celebrity from its possession of rich and extensive deposits of magnetic iron ore, occurring in pockets, has an area of 5,530 acres, of which 2,830 acres are under cultivation. Of this estate a writer in the *Newcastle Chronicle* says: "Not until the North Yorkshire and Cleveland Railway had been transferred to the North-Eastern in 1859, and the latter company began to carry out to completion the line by extending it from Stokesley to Grosmont, and by forming the Rosedale Branch to Ingleby a year after the date last named, was there any likelihood of enlarged mineral traffic from the dale. In 1861 the Rosedale Branch was completed, and from that date, for years, the mineral output of the mines began to increase." This development appears in the following table, the output of the year 1857 amounting to 7,500 tons :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1861	79,786	1871	314,394
1862	219,123	1872	303,205
1863	224,889	1873	560,668
1864	297,580	1874	473,140
1865	250,000	1875	383,914
1866	230,382	1876	383,827
1867	178,227	1877	344,487
1868	210,082	1878	234,150
1869	269,595	1879	25,592*
1870	317,000	1880	9,188

* Mines closed in March, 1879, and operations resumed by a new company in 1880, when the above quantity was raised, the value at the pits being about 3*s.* per ton put in trucks.

The ironstone mines of Cleveland, their situation and proprietors, were as follows in the year 1881 :—

CLEVELAND AND WHITBY DISTRICT.

No.	Name of Mine.	Situation.	Name of Proprietor or Company.	Name of Manager or Agent.
1	Ailesbury . . .	Swainby . .	Carlton Iron Ore Co., Limited . . .	Robt. Bell.
2	Huntcliff . . .	Saltburn-by-the-Sea.	Bell Brothers, Limited	Thomas Bell, junr. A. L. Steavenson.
3	Cliff	,,	,,	,,
4	Carlin How . . .	,,	,,	,,
5	Normanby . .	Middlesbro' . . .	,,	,,
6	Park, in Cleveland .	Skelton . . .	,,	,,
7	Skelton . . .	Marske-by-the-Sea .	,,	,,
8	Chaloner . . .	Guisborough .	Bolckow, Vaughan & Co., Limited . .	Thomas Lee.
9	Eston	Middlesbro'-on-Tees.	,,	J. Thompson.
10	Longacres. . .	Saltburn . . .	,,	George Robinson.
11	Skelton, North . .	,, . . .	,,	,,
12	Cragg's Hall . .	,, . . .	J. W. Pease & Co. . .	Wm. France.
13	Lingdale . . .	Guisborough . .	,,	Christopher Heslop.
14	Lofthouse. . .	Loftus . . .	,, . .	Wm. France.
15	Tocketts . . .	Guisborough . .	,, .	Wm. Walton.
16	Upleatham . .	Marske-by-the-Sea .	,, . .	W. Moore.
17	Whitecliffe . .	Saltburn . . .	,, .	William France.
18	Liverton . . .	Loftus . .	Liverton Ironstone Co., Limited . . .	G. Lee. Francis Fox.
19	North Loftus . .	Saltburn . .	Skinningrove Iron Co., Limited . . .	J. Westray.
20	Port Mulgrave and Grinkle . . .	Near Saltburn-by-the-Sea . .	Palmer's Shipbuilding and Iron Co., Lim.	A. S. Palmer.
21	Rosedale Abbey, East	Pickering . .	Rosedale and Ferryhill Iron Co., Limited, Martin Morrison, manager . . .	John Roscamp.
22	,, West	,, . . .	,,	Charles Parkin.
23	,, Sherriff	,, . . .	,,	,,
24	Grosmont . . .	Grosmont (York)	Charles and Thomas Bagnall, junr. . .	W. Armstrong. Francis Lord.
25	Brotton . . .	Saltburn Brotton. .	Morrison & Co. . .	D. W. Dixon.
26	California . . .	Grosmont. . .	..	..
27	Belmont . . .	Guisborough .	Weardale Iron and Coal Co., Limited . .	Thos. Allison.
28	Spawood . . .	,, . .	,,	,,
29	Kirkleatham . .	Redcar . . .	Kirkleatham Ironstone Co.	William Walker.
30	Boosbeck . . .	,, . . .	Stevenson, Jaques & Co.	,,
31	Slapewath . .	Guisborough . .	B. Samuelson & Co. .	Wm. Charlton.
32	Ormesby . . .	Middlesboro' . .	Cargo Fleet Iron Co .	William Walker.
33	Skelton, South. .	Saltburn . .	The Owners of Clay Lane Iron Works .	John Thompson.
34	Spa . . .	Guisborough . .	Gjers, Mills & Co. .	John Tate.
35	Lane Head . .	Rosedale Abbey . .	Robt. Hansell . .	Robt. Hansell.
36	Wintergill . . .	Egton Lythe . .	J. Foster and Son . .	..
37	Stanghow. . .	Saltburn . . .	Stanghow Ironstone Co.	E. Hamilton.

Having considered the vast deposits of ironstone in the Cleveland district, it will now be a fitting time to refer generally to some of the difficulties met with in ironstone mining, and of the machinery employed to aid the miner in the operation. A writer in the *Colliery Guardian,** well acquainted with the district and quoting from Mr. A. L. Steavenson's interesting paper "Ironstone Mining in Cleveland," † says that, "owing to the irregular

* Nov. 26th, 1880. † "Journal of the Iron and Steel Institution," 1874, p. 329.

character of the strata in some parts and the configuration of the country in others, the mining of these immense deposits of ironstone is carried on under various conditions. At the outcrop of the main seam at Eston it is 300 feet above the level of the sea, and dips thence at the rate of three inches to the yard until it is 100 feet below sea level under the centre of the hill, whence it rises as rapidly till it crops out again at the other side of the hill, not to mention several faults or dislocations of considerable magnitude. In other parts, such as at the Kilton Winning, large feeders of water, amounting sometimes to 1,000 gallons per minute, make both sinking and working an operation of more than ordinary difficulty. Perhaps the largest feeders of water have been encountered at the North Skelton Mines. At a depth of 64 fathoms the 'Top seam' was reached, 3 feet 6 inches thick, but even at that depth the water had to be forced at the rate of 3,000 gallons, or nearly 15 tons a minute. Incidentally it may be observed, that towards the end of 1880 the depth attained at this mine exceeded 720 feet, when the ironstone was reached and is now worked."

"When the extraction of ironstone began in 1850 at Eston it was only necessary to uncover the outcrops and then quarry it out in large quantities, but as the covering increased in thickness as the working proceeded, drifting became necessary; and ultimately as the water feeders increased deep shaft sinking had to be adopted. Both drifts and shafts are now extensively in use, the expediency of adopting the one or the other being determined by the nature of the local circumstances. The getting of the ironstone is mostly accomplished by blasting, and for this purpose gunpowder is the best explosive. Many other kinds of explosives have been tried, but the oldest is still considered the best. The operations of the miners are facilitated by the occurrence, often at short distances apart, of joints called 'backs.' The mode of operation is as follows: Cylindrical holes are drilled, varying from two to five feet deep. The boring of these holes is the chief work of the miners, less skilled men being employed to break up the stone and fill it into waggons. A good miner can drill a hole of 5 feet in an hour. Different kinds of machines have been tried for the purpose of drilling these holes, but none of them have been so successful as to entirely supersede hand labour. Probably 15,000 tons of gunpowder are consumed yearly in blasting the ironstone

of Cleveland. The use of such large quantities of this explosive adds considerably to the impurity of the atmosphere in the mines; hence various mechanical appliances are generally employed to improve the ventilation."

The importance of suitable machinery to aid the miner in his labour of getting the ironstone is a point of especial interest. Mr. Windsor Richards recently, in his address to the members of the Cleveland Institution of Engineers, remarks, "There is no industry of more importance to this district than that of the ironstone mining, and the economical production of ironstone can scarcely be over-rated when it is remembered that about 3½ tons are necessary for the manufacture of a ton of pig-iron. Machinery has already been introduced for winning the stone, and its improvement and extension are well worthy of careful attention." Mr. Richards continues his observations by the following interesting sketch of rock drills and their adoption at the North Skelton Mines. He says, "I believe that Mr. William Walker, of Saltburn, was the first to introduce machinery into the Cleveland mines. He adopted the ordinary rotary spiral drill, driven by a pair of small engines worked by compressed air. Before deciding on the kind of drill to be adopted at the North Skelton Mines, where the ironstone is extra hard, he carefully investigated many of the rock drills in use, and finally determined upon the percussive system, the drills being of simple forms, requiring such slight repairs as can be effected by the ordinary blacksmith at the mine. At the North Skelton Mines there are at present seven machines at work, which are distributed over certain districts. Each district consists of ten working places. A direct-acting horizontal engine, fixed on the surface, having 20-inch steam and 22-inch air cylinders, 4-feet stroke, supplies air to the machines at a pressure of about 70 lbs. per square inch. The engine is sufficiently powerful to work twelve machines. The compressed air is forced down the shaft and along the main roads, east and west, in 6-inch pipes. The pipes along the roadway are 4-inch diameter. The machines have 2-inch and the working places 1-inch wrought-iron galvanised pipes. At present each machine only produces about 50 tons of ironstone per shift of eight hours, but a machine has occasionally got 75 tons, and in a few instances 96 and even 107 tons in eight hours. For 50 tons of ironstone got, about 25 holes 1 inch in

diameter have to be bored to a depth varying from 3 feet to 5 feet, according to the hardness of the stone, or about 100 feet depth of ironstone pierced per machine per eight hours. After being placed in position the drill bores the stone at the rate of 16 inches per minute, or a hole 4 feet deep can be readily made in six minutes, including the time for changing the drills; whereas an ordinary miner would take fully sixty minutes to put in a hole 4 feet deep by 'tamping' or 'jumping' with a bar in the usual way; so that the machine does easily the hardest and most fatiguing work of the miner. One machine employs two miners and a boy, who attend to the drilling and blasting, and four labourers, who break up and fill the stone into the tubs or waggonettes. Ironstone mining by machinery is comparatively new in the district, and the miners have not yet got well into the way of using it; but there can be no doubt that with ordinary diligence one machine can produce from 70 tons to 80 tons of stone per eight hours' shift. The kind of machine adopted at North Skelton is that known as the 'Burleigh,' the principal parts of which are the cylinder, piston, the cradle, with guide stays in which the cylinder travels, and the drills. The piston travels backwards and forwards at a rate which gives 300 blows per minute, and for eighteen blows given it revolves once. The cylinder moves along the cradle, and is fed by a screw worked by hand, automatic gear for this purpose having been found so far unsuitable, owing to the various degrees of hardness of the stone to be bored. As soon as the drill has been fed in the 2-feet length of screw it is withdrawn, and a longer drill substituted. Drills are made of different lengths, and the points of various forms. The half-moon shapes are very suitable for the first and second drills to a depth of 3 feet. The air exhausted from the machines has a beneficial effect in ventilating the working places. The success of this machine, or, indeed, of any other, depends upon the handiness and simplicity of the carriage on which it is mounted. The carriage has received very careful attention from Mr. Chisholm, the engineer of the mine, and is very ingeniously arranged and well adapted for its work. The carriage must be constructed so that it can be very quickly brought up to its work, and be quickly removed to another working place. It must allow the drills to work at any angle, and to drill at any point of the working face."

Distribution of Cleveland Ironstone.—The great bulk of the ironstone raised in the Cleveland Hills is reduced to the metallic state in the furnaces of Cleveland and those of Durham and Northumberland, ample facilities for its transport being afforded chiefly by the North-Eastern Railway and its numerous branches. The total quantities of Cleveland ore carried in each year by the above-named railway include those hematite ores carried from the north-west coast of Lancashire and Cumberland, and other districts, while the annexed statement, showing for a few years the quantities used in the furnaces of Durham and Cleveland, and the total quantities of all kinds of iron ore carried by the North-Eastern Railway, will indicate generally the distribution of the ironstone :—

Year.	Cleveland Furnaces.	Durham Furnaces.	Total carried by North Eastern Railway.
	Tons.	Tons.	Tons.
1872	2,955,000	2,100,000	4,652,052
1873	2,920,000	2,392,000	4,928,458
1874	2,980,500	2,280,000	4,904,279
1875	3,296,824	2,050,852	5,305,113
1876	3,524,962	2,030,000	5,426,576
1877	3,980,770	1,972,395	5,547,821
1878	3,850,045	1,642,149	4,999,448
1879	3,380,015	1,253,850	4,190,050
1880	4,463,229	1,603,905	5,785,724

Considerable quantities of iron ore will also have been carried direct from the mines to the furnaces without passing over the North-Eastern system.

Population Employed in Iron Mining.—Until the year 1873 our information of the number of persons employed in the North Riding of Yorkshire or Cleveland district was not accurately known. In 1873 it was, for the first time, ascertained that the number of persons engaged in iron mining amounted to 9,350, of whom 6,947 were engaged in underground operations, and 2,403 above ground ; producing * 5,435,233 tons of ironstone, or an average of 581 tons per person. Since 1873 the numbers employed, the ironstone raised, and average output per man, have been as follows :—

* Reports of H.M. Inspectors of Mines.

Year.	Persons Employed.		Total.	Ironstone Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	6,947	2,403	9,350	5,435,233	581
1874	7,571	2,274	9,845	5,428,487	551
1875	7,660	2,128	9,788	6,085,541	623
1876	7,810	2,041	9,851	6,564,101	667
1877	6,983	1,586	8,569	6,289,745	735
1878	5,654	1,137	6,791	5,316,477	784
1879	6,031	1,128	7,159	4,714,535	695
1880	6,500	1,472	7,972	6,441,783	808

In the last named year there were 44 iron mines in the district comprising 53 separate pits or drifts, but of the mines 8 were standing, compared with 18 in the previous year.

Resources of the Cleveland Ironstone District.—According to Bewick, who first directed attention to this subject, the estimated area of the main bed of Cleveland ironstone was 420 square miles, and taking the average yield per acre at 20,000 tons, he estimated the contents at 5,000,000,000 tons. In 1863 Mr. I. Lowthian Bell, in his paper on "The Manufacture of Iron," read before the British Association,* basing his calculation on the researches of Messrs. Hugh and J. T. Taylor and T. Young Hall, &c., estimated the resources of the Durham and Northumberland Coal-field at six thousand million tons for future use, so that there is sufficient fuel in the one district—reserving it for that purpose exclusively—to smelt the ironstone of the main seam of the other. The subject was again considered in the year 1871 by the "Iron Ore Committee of the Iron and Steel Institute," who reported as follows. They said, "It is now tolerably well known that after leaving the Eston Hills, the ironstone in which has occupied three square miles, the district from which the chief supply of stone is to come for the next century comprises a length of nearly six miles from the vicinity of Guisborough, south-east to the coast, with an average width of four miles. It has been proved that over the greater part of this area the main seam occurs in an unbroken state, varying in workable thickness from 9 to 13 feet, and having about the same

* "British Association Papers, 1863," p. 60.

per centage of metallic iron throughout. Towards the south the stone does get slightly leaner however, by from one to two per cent., and it also steadily thins off; but for the purposes of this estimate the whole district may be taken collectively, and the stone regarded as uniform throughout. The total area of this tract, including the Eston Hills, is 27 square miles, or 17,280 square acres. It is calculated that from the discovery of the Cleveland ironstone to the end of 1870, the total quantity of stone smelted has been 45,000,000 tons, which at 30,000 tons per acre, gives 1,500 acres worked out in twenty years, of which the greater portion has been in the locality a few miles of Middlesborough. The present rate of working is at the rate of 150 acres per annum, and this will be rapidly increased. But the mining-field under notice yet contains say, 16,000 acres untouched, so that at the rate of extraction prevailing in 1870 there is a supply of stone, in this part of Cleveland alone, sufficient to last 100 years, without taking into consideration the iron ores of Rosedale and other places outside the locality in question. But there is every reason to believe that beyond the boundaries of this known district the main seam extends underneath the whole country as far as Whitby and the Valley of the Esk, although it is impossible to speak with any certainty as to the changes that may occur in the quality or thickness of the seam in the direction indicated."

Now, accepting the estimates of the "Iron Ores Committee" and making necessary deductions for production of the past ten years, the acreage now available (1880) would not exceed 14,000 acres of the main seam of Cleveland, which at the present rate of exhaustion would afford supplies for seventy years to come.

Recently the resources of the Cleveland district have been treated in an exhaustive paper read before the Cleveland Institution of Engineers, Middlesborough,* and the results arrived at generally coincide with those of the Iron Ores Committee as to the contents of the main seam. Mr. Barrow's investigations are embodied in the following account. He says:—

"There are, in Cleveland, two distinct classes of iron-stone, the better being blue, very oolitic, and comparatively free from aluminous matter, yielding about 30 per cent., or rather more,

* By Mr. George Barrow, F.G.S., of the Geological Survey of England and Wales.

of metallic iron; the second-class stone is of a dull yellowish tinge, not so oolitic, and contains alumina in place of the iron, which is lost, 28 or 29 per cent. being as much iron as is usually extracted from it. This deterioration in quality of the stone is accompanied by a serious drawback to its being cheaply worked, for, towards (slightly below) the middle of the seam, a band of shale gradually comes in, thickening in a southerly direction till it reaches its maximum thickness of 2 feet, which is the amount of shale between the upper and lower parts of the main seam at Grosmont, the seam being quite unworkable in that district.

"In order to fix the limits of the good stone, it is necessary to know its outcrop, and also the line marking the limit of the shale band in the middle of the seam. The former I have carefully mapped out on the six-inch maps of the district. The limit of the shale band, in the middle of the seam, may be roughly described by a line joining the road at Spa Wood, near Guisborough, to the north side of South Skelton shaft, thence on to Hummersea on the coast, a little more than a mile east of Skinningrove Beck. All the good stone lies north of that line in an area consisting of three distinct parts: Eston, Upleatham, and the Skelton and Huntcliffe district.

"Commencing with the Eston outlier, Eston may be considered as consisting of Eston Royalty proper, and the smaller Royalties of Normanby, Ormesby, and Dunsdale, calculating the seam as of so many 'foot-acres,' *i.e.*, acres one foot in thickness.

"Eston, then, consists of 24,000 foot-acres, very nearly. The specific gravity of the stone is about 2·6, and, as a cubic-foot of water weighs 1,000 ounces, a foot of stone weighs 2,600 ounces, and an acre one foot thick weighs 3,610 tons. Hence we have roughly 86,640,000 tons in Eston Royalty.

"Similarly, there are 2,300 foot-acres in Normanby, and 8,300,000 tons of stone. Also in Ormesby there are 720 foot-acres and 2,600,000 tons of stone. There are 900 foot-acres in Dunsdale, or 3,250,000 tons of stone. In order to tell how long these mines will last, it is necessary next to know the average amount of stone taken yearly out of each, and the total taken.

"In consequence of the Mining Record Office returns, prior to 1865, being incomplete, it is obvious that the total obtained from this source of information will be much under the mark, in the case of Eston, Upleatham, and Normanby, as in 1865 they were

in full swing, turning out almost as much stone as at present. Still, I shall make the calculation from 1865, making a small allowance for cases when considerably more stone has been taken than is represented by this total."

"From such information, then, we arrive at the following result:—The yearly output of Eston is 800,000 tons; of Normanby, 225,000 tons; of Ormesby, 75,000. The total of ironstone removed in Eston, 16,000,000 tons; in Normanby, 5,000,000 tons; in Ormesby, 500,000 tons. Now, if we deduct the total taken out from the whole of the stone in a mine, and take away at least one-tenth for loss in working, we have for the quantity now left—

	TONS.
In Eston	60,000,000
,, Normanby	2,500,000
,, Ormesby	1,800,000

Hence, dividing these totals by the average yearly output, we find, for the continued duration of each mine,—

For Eston	75 years.
,, Normanby	8 ,,
,, Ormesby	15 ,,

"Proceeding in a similar way for the Upleatham district, the total stone amounts to 10,000 foot-acres, or 36,100,000 tons. The yearly output is 700,000 tons, and the total taken out considerably over 12,000,000 tons, so that its duration will be some 30 years, or rather less—between 25 and 30.

"The area of good stone left in Skelton and Huntcliffe districts consists of 48,000 foot-acres, or 173,280,000 tons. The yearly output is about 1,800,000 tons, and the total output 24,190,000 tons, or more. Hence the workable quantity left is about 145,000,000 tons, which would, at this rate, last 80 years. But, taking into consideration the increased call 30 years hence, 60 years would be a fair limit to put to the duration of the stone.

"Now, the main seam in the poorer districts may be said to consist of a strip 13 miles long, by about 2½ miles wide. South of this the seam is very poor and thin, and consists of 4 feet of stone, with a two-feet shale parting in the middle. Before it would pay to work this, other seams will be wrought; in fact, these seams will be worked before many years, because, though

thin, their quality is better than any, except the very best stone. The total amount in this strip, then, of the inferior stone, which pays to work now in fairly good times, is, roughly, 375,480,000 tons, and, at the present rate of output, would last some 130 years; but this period would be much lessened, as in 30 years the output would be more than doubled to compensate for the exhaustion of the Upleatham and other mines."

Mr. Barrow subsequently considers, in detail, the district in which the main seam occurs, where it is at present regarded as almost valueless, "and defines the area of the poorer stone 13 miles long and 2½ miles broad, as extending in a line roughly drawn from Kildale, south of Guisborough, to Kettleness, north of Whitby, as its southern boundary. At Kildale, the section of the seam consists of 4 feet of stone, with a shale parting of 14 inches, and again, on the Commondale shaft the seam may be said to consist of three-two's. At Grosmont, the seam has become so thin as to be almost unrecognisable. It must be borne in mind that this bed is in all cases of a decidedly poor quality, and so up to Kettleness, where the average yield is 26·5 per cent. of iron. South-east of Kettleness iron has not been seen or proved.

"Taking into consideration the poverty of the seam in Hawkser, south of Whitby, where the seam is represented by a few doggers, it is evident it will not be used as a source of iron for many years to come, if ever. Coming to the consideration of the other seams of ironstone in Cleveland not usually worked, examining the main seam at Eston, it would be found, at the base as at present worked, to consist of a greenish, shaly stone, having a rather mottled appearance. Before reaching the south or east face of the hill, a shale-band comes in between the oolitic stone and green stone, but only the oolitic was taken up in a long drift which was made some time ago on the Chaloner property, the shale and underlying shelly bed being left. The shelly bed is contained over a very large area, and is in fact the Pecten seam at Grosmont, and in future it would be far safer to restrict the term to this bed, calling the thick, blue stone usually found the main seam. It is usually of a poor quality, yielding about 27 per cent. of iron, or slightly less. It is difficult to estimate the amount of ironstone in this seam, because it varies very much according to presence or absence of the shaley streaks. It probably cannot be worked separately under Eston, nor in the

Upleatham district, but at the Old Hutton mines it seems to have been taken near the outcrop, its thickness being 3 feet 6 inches, at a depth of about 4 feet from the base of the seam.

"Again, at Kildale the shale is 2 feet 6 inches thick, and this belt is exposed at Spa Wood railway cutting, where its thickness is 4 feet. At Huntcliffe, and at Brotton, it is very thin, but at Longacres Pit it is 3 feet thick. At Grosmont its thickness varies from 2 feet 4 inches to 2 feet 6 inches of stone, with a shale parting in the upper part. Calculating that it covered an area of 50 square miles, with an average thickness of 2 feet 6 inches, it was estimated that there should be a total of 400,000,000 tons of ironstone from this seam, which was, however, of poor quality, and not always reliable. About 5 feet 6 inches below the Pecten seam occurs a bed of stone, remarkable for its uniform thickness and its good quality. In many places, such as Normanby and Brotton, it seemed to be equally rich in iron with the main seam, its thickness usually being about from 1 foot 10 inches to 2 feet. It maintains this thickness over a very large area, being 2 feet 6 inches at Kildale ; 1 foot 10 inches at Guisborough ; and 2 feet 2 inches at Hob Hill.

"On the coast at Staithes the seam shows signs of thinning, being about 1 foot 8 inches, so that they might put its south-eastern limit about three ; but it continues some distance in the Stokesley range of hills, being worked for some time in the Ingleby Mine, after the main seam had been abandoned. The estimated area of this seam would be about 60 square miles, with an average thickness of 2 feet. It is mostly a clean stone, and will yield a total of about 380,000,000 tons of first-class stone.

"Below this seam is the 'Avicula' seam so well known at Grosmont. The avicula seam is very permanent, but its thickness varies very much over the whole of Cleveland, ranging from 8 feet at Grosmont, to as little as 1 foot 6 inches at Staithes, its average yield of iron being about 27 per cent. This seam also extends into the Stokesley Hills down Bilsdale, but it would be hazardous to say that it could be worked for a great distance from any given point. Its estimated area would extend over 100 square miles, and the probable amount of stone would be somewhere about 600,000,000 tons, probably more, but its working, except where it could easily be proved first, would be very venturesome. This concludes the account of the seams of ironstone in the liassic

beds, and it only remains to consider those ironstone seams in the oolitic beds. Of these there are but two, one being the Dogger, or top bed, and the other the Eller Rock. The Dogger occurs at the top of the Alum shale, and as a general rule it may be defined as a sandy ironstone or a ferruginous, impure limestone. It is always remarkable for the so-called pebbles in it. At Eston, Upleatham, Guisborough, &c., it may be practically said to be non-existent.

"From the peak at Robin Hood's to Runswick Bay, on the coast all along Eskdale, Glaisdale, Muske, Esk, &c., it is a highly siliceous, oolitic ironstone, varying from 2 feet to 16 feet thick. It has often been tried at Eskdale, Grosmont, and Muske Esk, but has always failed. About Staithes, Boulby, Huntcliffe, and Liverton, the Dogger consists of a hard band of very fine clay ironstone, containing about 40 per cent. of iron, resting upon a ferruginous marl, often containing as little as 25 or 26 per cent. One of the most characteristic features of the top bed is its fickleness, being unreliable for any great distance. The per centage of impurity in the two marly beds will determine whether this seam can ever be worked, and the same remarks will apply to Huntcliffe, where the section is much the same. At Boulby Alum Works the seam is slightly thinner, but presents the same general characteristics; at Grinkle Park the seam is very thin and sandy; it is apparently absent at North Skelton Shaft, and is entirely wanting at the Hagg Alum Works, near Saltburn. The area, over which this seam may possibly be worked in Cleveland at some future time, is between four and five square miles, its average thickness being 3 feet 6 inches. In the Stokesley Hills the main seam occurs in cuticular patches, lying in eroded hollows in the alum shale. In all cases it contains much lime and silica, which in Bilsdale has been burnt for lime.

"At Limekiln Bank, over Swainby, it becomes 28 feet thick, valueless as a source of iron, and at Catcliff Bank, near North Allerton, the seam attains, in one place, a thickness of nearly 20 feet, but there are shaly partings in it, and most of the ironstone is of poor quality; in fact, it is of no value as iron ore. In Rosedale, however, a wedge of ironstone, formed similarly to that referred to in Bilsdale, occurs, in which all the lime has been probably replaced by iron, and where a rich iron ore has been found, but its extent has not hitherto been ascertained."

Pig Iron Manufacture.—The ironstone deposits of Cleveland

were first developed about the year 1850, and the smelting of the stone in the district soon followed, and so rapidly, that in the year 1855 there were 23 furnaces built, 21 of which were in blast and produced 84,500 tons of pig-iron. The early furnaces erected in the district varied in height from 42 to 50 and 55 feet, their capacity varying from 5,000 to 6,000 feet; about the year 1861 furnaces of greatly increased capacity were erected at the Thornaby Ironworks by Mr. William Whitwell, three in number, each of a cubical capacity of 12,778 feet; these furnaces were 60 feet in height and 20 feet diameter in the boshes. Considerable economy was secured in the consumption of fuel in manufacture by these larger furnaces, so much so, that in 1866 the Messrs. Hopkins, Gilkes & Co., at their Tees Side Ironworks, erected two furnaces, each 75 feet in height and 24 feet in the boshes, and a capacity of 20,000 cubic feet.

The results attained by these large furnaces were so encouraging that still larger ones were erected, one having a height of 105 feet, and a cubical capacity of 41,150 feet. But it has since been determined that with these extraordinary dimensions the limit of economical working has been exceeded.

In the year 1855, above referred to, the works and firms in operation, with the number of furnaces built and in blast, were as follows, the make of pig-iron being, as previously stated, 84,500 tons:—

No.	Name of Works.	Name of Firm.	Furnaces.	
			Built.	In Blast.
1	Tees . . .	Gilkes, Wilson & Co. .	4	4
2	Eston . . .	Bolckow & Vaughan .	6	6
3	Cleveland . .	T. L. Elwen & Co. .	3	2
4	Middlesborough .	Cochrane & Co. . .	3	3
5	Ormesby . .	Bolckow & Vaughan .	4	3
6	South Bank . .	B. Samuelson & Co. .	3	3
		Total .	23	21

Several new works were projected and commenced about this period. The works of the Clay Lane Iron Company began the manufacture of pig-iron, towards the close of 1858, with one furnace, blowing in a second in the following year. The Tees Side furnaces of Messrs. Snowden & Hopkins followed in 1859,

and in 1860 the furnaces of the Whitby Iron Company were put in blast; the total number of furnaces built in the district at this time being 33, of which number 25 were in blast, the works previously established in the mean time adding to their number of furnaces, and thus increasing their resources for production in the future.

The works at Normanby, of Messrs. Jones, Dunning & Co., commenced operations, in 1861, with two furnaces, followed in 1863 by the Grosmont Works, of Messrs. Charles and Thomas Bagnall, with two furnaces in the early part of the year; and the Newport Works, of Messrs. B. Samuelson & Co., with three furnaces in August of the same year.

The works at Cargo Fleet, of Messrs. Swan, Coates, & Co., were completed towards the close of 1865, and in June, 1866, two furnaces were blown in. These were succeeded by the Linthorpe Works, of Messrs. Lloyd & Co., where four furnaces were blown in about August of the same year. In the following year the Glaisdale Works, of Messrs. Firth & Hodgson, and situated near Whitby, were put in operation. Other works followed: the Ayresome, of Messrs. Gjers, Mills & Co., in 1870; the Carlton, of the Industrial Iron Company, and the Norwegian, of the Titanic Iron Ore Company, with one furnace; and those at Ayresome and Carlton with two each in the same year, when the total number of furnaces in the Cleveland district was 74, of which number 67 were in blast, producing in that year 916,970 tons of pig-iron.

In 1871 the Lackenby Iron Company, with two furnaces, commenced the manufacture of pig-iron, a third being in course of erection; and in 1873 the Coatham Works, of Messrs. Downey & Co., with two furnaces; these were followed, in 1874, by the Acklam Works, of Messrs. Stevenson, Jaques & Co., with four furnaces; the Loftus, Redcar, and Stockton Ironworks; and in 1875 by the Thornaby Ironworks, of Messrs. William Whitwell & Co., each with two furnaces. The Loftus Ironworks have recently been acquired by a new company, and are now known as the Skinningrove Works, the company being incorporated on the 8th June, 1880, since which date a few changes of proprietorship have occurred in other works. In the annexed table is given the numbers of furnaces built and in blast, the make of pig-iron, and the average yield per furnace in each year since 1855:—

Year.	Furnaces.		Pig-Iron made.	Average per Furnace.
	Built.	In Blast.		
	Nos.	Nos.	Tons.	Tons.
1855	23	21	84,500	4,024
1856	31	23	179,400	7,800
1857	32	23	179,838	7,816
1858	30	20	189,320	9,466
1859	30	23	216,127	9,400
1860	33	25	248,665	9,946
1861	33	26	234,656	9,025
1862	32	28	283,398	10,121
1863	42	33	315,197	9,551
1864	47	41	409,106	9,979
1865	65	53½	486,421	9,011
1866	67	55½	546,091	9,839
1867	67	50½	640,892	12,699
1868	69	50	699,494	13,989
1869	69	51	766,410	15,027
1870	74	67	916,970	13,686
1871	75	70	1,029,885	14,713
1872	81	73¾	1,122,114	15,215
1873	78	76	1,156,431	15,216
1874	97	85	1,158,471	13,629
1875	87	73	1,240,243	16,990
1876	86	75	1,261,013	16,813
1877	89	75	1,374,582	18,314
1878	90	67	1,358,442	20,275
1879	90	70	1,210,091	17,287
1880	91	72	1,666,156	23,141

The apparent want of constancy in the average yield per furnace in 1879 is due to the fact of several of the furnaces being but partially in operation during that year. Bearing upon the production per annum per furnace of this district, Mr. Windsor Richards, recently in his address to the Cleveland Institution of Engineers, refers to the Cleveland furnaces in these words; he says, "Some years ago this district took the lead in blast furnace construction and practice, and may still be proud of its best examples of blast furnace plant, but latterly few improvements have been made. In 1876 the output of Cleveland pig-iron per furnace per week amounted to 330 tons; in 1877, to 317; in 1878, to 406 tons; and in 1879, to 417 tons; and this year (1880) the output will be about 427 tons, showing but small progress. Some few furnaces in the district have made regularly over 500 tons per week. The manufacture of Bessemer pig-iron, Spiegeleisen, and ferro-manganese, is becoming a large industry

in Cleveland. Before 1876 there was no separate account kept of Bessemer pig-iron made in the Cleveland district. Since that date the production has been as follows:—

YEAR.	TONS.
1876	125,000
1877	200,000
1878	339,131
1879	274,939

"The falling off in 1879 was owing to the Durham miners' strike, and bad trade, and this year (1880) it will probably be 500,000 tons. The total production of the blast furnaces of the North of England district will probably reach the enormous total of 2,490,000 tons."

Mr. W. Richards gives some interesting details showing the efficiency of the metallurgical operations at the Consett Ironworks in Durham, and says: "A blast furnace practice, in the manufacture of Bessemer pig-iron, worthy of imitation, is that of Mr. William Jenkins, of Consett, who, at my request, furnished me with the following information, and the results show what I believe to be the best blast furnace in England. The figures are for eight consecutive weeks in hematite pig-iron:—Iron produced, 6,454 tons 13 cwts.; average per week, 806 tons 17 cwts.; 53 per cent. of the make being No. 1 quality. Coke used per ton of iron made, 19·21 cwts. The furnace is 55 feet high, 20 feet diameter at the bosh; 8 feet hearth; 7 tuyeres; 4-inch muzzles; blast, 4¼ lbs. pressure per square inch. There are four Whitwell stoves, 22 feet diameter, 28 feet 6 inches high, each stove having a heating surface of 8,200 feet; temperature of the blast averages 1,200 deg. Fahr. Mr. Jenkins attributes these good results to the better distribution of the blast, large hearth, better lines of furnace, and good heat." According to Mr. W. Richards, the average yield of the furnaces of the Cleveland district has been as follows during the ten years ending 1879; output per annum per furnace—

Year.	Tons.	Year.	Tons.
1870	14,491	1875	17,653
1871	15,196	1876	18,693
1872	15,146	1877	20,045
1873	15,148	1878	20,645
1874	16,009	1879	20,016

It only remains to append the following list of works and owners, with the number of furnaces built and in blast in the year 1880 :—

No.	Name of Works.	Owners.	Furnaces.	
			Built.	In Blast.
1	Acklam, Middlesbro'	Stevenson, Jaques & Co.	4	4
2	Ayresome, Middlesbro'-on-Tees	Gjers, Mills & Co.	4	4
3	Cargo Fleet, ,, ,,	Cargo Fleet Iron Co.	5	4
4	Clay Lane, Eston Junction	Owners of Clay Lane Ironworks	6	3
5	Coatham, Middlesbro'	Downey & Co.	2	2
6	Middlesbro'	Bolckow, Vaughan & Co., Lim.	3	3
7	Eston (Iron and Steel)		11	11
8	Glaisdale (Yarm)	South Cleveland Ironworks Co. Limited	3	..
9	Grosmont, Whitby	Chas. and Thos. Bagnall, jun.	3	2
10	Lackenby, Middlesbro'	Downey & Co.	3	3
11	Linthorpe ,,	Edward Williams	6	3
12	Skinningrove	The Skinningrove Iron Co., Lim.	2	2
13	Newport, Middlesbro'	B. Samuelson & Co.	8	8
14	Normanby, ,,	Jones, Dunning & Co.	3	3
15	Ormesby, ,,	Cochrane & Co.	4	4
16	Redcar	Walker, Maynard & Co.	4	4
17	South Bank, Middlesbro'	Bolckow, Vaughan & Co., Lim.	8	8
18	Tees, Middlesbro'	Wilson, Pease & Co.	5	5
19	Tees Side, ,,	Tees Side Iron & Engine Works Co.	4	4
20	Thornaby, Stockton	William Whitwell & Co.	3	3
		Total of North Riding	91	80

Distribution of Cleveland Pig-Iron.—The pig-iron is widely distributed at home and abroad, and is increasing yearly. The total quantities shipped to foreign countries, and to other parts of the United Kingdom, from the port of Middlesborough during the four years ending 1880, were as follows :— *

Year.	Foreign.	Coastwise.	Total.
	Tons.	Tons.	Tons.
1877	321,946	460,390	782,336
1878	337,559	422,480	760,339
1879	395,658	419,905	815,563
1880	495,638	464,943	960,581

The foreign countries receiving the shipments in each of the same years appear in the annexed statement :—

* Cleveland Iron Masters' Association Returns, 5 Jan., 1881.

Countries.	1880.	1879.	1878.	1877.
	Tons.	Tons.	Tons.	Tons.
Germany	110,611	106,681	96,801	90,368
Holland	69,684	68,732	72,930	67,660
France	68,085	53,809	61,297	68,946
Belgium	73,144	44,565	50,270	41,620
Sweden	12,487	8,776	10,162	11,290
Norway	5,385	7,758	6,763	12,763
Spain	18,695	23,223	12,311	9,377
Portugal	6,328	10,250	11,592	4,901
Russia	33,454	22,060	9,000	7,199
Denmark	4,243	3,162	1,883	3,720
Italy	1,645	2,967	3,495	3,987
Jersey	...	75	80	...
India	250	...	270	125
Japan	900	...	550	...
China	300	...	...	...
Austria	140	600	...	...
B. N. America	...	1,000	205	...
U. S. America	90,087	42,000	...	...
Egypt	200	...	...	...
Total	495,638	395,658	337,559	321,946

The shipment coastwise, and the respective ports receiving the same, were as follows in each of the same years :—

Ports.	1880.	1879.	1878.	1877.
	Tons.	Tons.	Tons.	Tons.
Scotland	283,463	285,846	330,554	317,249
Wales	89,204	70,267	58,740	60,339
Newcastle	52,332	35,492	30,716	48,478
Other ports	39,944	28,300	32,470	34,324
Total	464,943	419,905	422,480	460,390

Average Price of Cleveland Pig-Iron.—Following the pages of those journals devoted to the progress of the iron trade, evidence is afforded of the very low prices of pig-iron in recent years. In 1873 the highest price that Cleveland pig attained in the market was reached, namely, £5 9*s.* 2*d.*, since which date it has receded, till in July, 1879, it was sold (No. 3) at 32*s.* per ton. An improvement appears in 1880, when the average of the year's quotations shows an increase of nearly 10*s.* per ton. The variations in previous years were as follows :—

Year.	Average.			Highest.			Lowest.		
	£	s.	d.	£	s.	d.	£	s.	d.
1868	2	3	2	2	9	6	2	3	0
1869	2	5	9	2	10	0	2	3	0
1870	2	10	3	2	13	0	2	7	6
1871	2	9	8	3	5	0	2	6	6
1872	4	17	1	5	15	0	3	5	0
1873	5	9	2	6	5	0	4	7	6
1874	3	10	11	4	7	6	3	0	0
1875	2	14	6	2	19	0	2	9	0
1876	2	7	10	2	13	6	2	5	0
1877	2	2	1	2	6	0	2	5	0
1878	1	18	2	2	1	0	1	14	6
1879	2	1	2	2	15	0	1	16	6
1880	2	10	6	3	9	0	2	2	0

The lowest price previous to 1878 was in 1868, when the average was but £2 3*s*. 2*d*.; and it is only necessary to add that the average price in 1879 increased, owing to the sudden impulse imparted to the iron trade in the last quarter of the year, when prices rose from 33*s*. to 55*s*. per ton.

Coal and Ironstone used in Manufacture.—Mr. Windsor Richards, who has carefully consided the question of fuel used in manufacture, and who has followed its economy, says, that "the improvements most conspicuous in recent blast furnace practice are to be found in the better means adopted for heating the blast in the Cowper and Whitwell firebrick stoves. It is difficult," he adds, "to ascertain the amount of coke consumed to make a ton of Cleveland iron, as blast furnace managers are very reticent on this point, but there is little doubt that the consumption of coke has of late years increased and is increasing, and the matter is so important to us as a district in the severe competition we have to contend with, that the following details, describing the alterations recently made in these stoves, to render them efficient and economical, will be interesting":—

"The Cowper stove is made much higher than formerly, so giving largely-increased heating surface, which reduces the temperature of the escaping gases at the chimney valve to about 400 degrees Fah., after having been on gas for three hours, thus utilising to the fullest practicable extent the waste gases of the former. The stoves are now made up to 25 feet diameter and 54 feet high, and have the enormous heating surface of 75,000 feet. With two such stoves to a large furnace the heat may be kept on

for four hours, with a loss of heat not exceeding 150 degrees. The combustion chamber, or flame flue, has been moved from the centre to the side of the stove, whereby the whole surface of the brickwork is rendered effective for absorbing and giving up heat. The gas is admitted at the bottom of this combustion chamber, and is split up into three parts so as to attain a more complete mixture of air and gas, which, in the increased diameter of the chamber, enables more gas to be consumed, giving a better flame to the centre of the flue. The simple means adopted of clearing the dust from the stove during tapping time (the man-hole floors are hinged, and can, by the aid of a long lever, be readily opened and closed) and the sudden letting out of the compressed air through these openings clears away some of the dust. Any dust which may be lodged in the stove can be got down by light charges of gunpowder fired through the 'sight-holes.' If these simple expedients are regularly attended to the stove can be kept continuously at work for many months together. There is also a specially constructed down-comer for the gas, with a contrivance for trapping some of the dust, and so prevent it from entering the stove. The bricks used in the regenerator are made larger than formerly, the size now preferred being 2 inches by 5 inches by 12 inches. There are also tiles placed over the very many passages to distribute the products of combustion equally over the whole regenerator. By these means the blast may be readily heated up to 1,500 degrees Fah. The hot-air valve, which used to be very troublesome in these stoves when they were first designed, now works very well, and without any water for keeping it cool."

Mr. W. Richards further remarks, in reference to the Whitwell stoves, that at several works which he lately visited—Cockeril, in Belgium; Denain, in France, and Millom—he noticed that the Whitwell stoves are being increased in height. Mr. Massicks, of Millom, has raised a set of stoves for one furnace from 28 feet to 40 feet, and finds that the temperature of the escaping gases from the 40 feet stoves, taken at the chimney valve, is 360 degrees Fah., and that of the 28 feet stove, taken under exactly similar circumstances, is 495 degrees Fah. Both of these were taken after having been on gas for three hours. This alteration, by increasing the heating surface, gives greater regularity of work in the blast furnace. These stoves are now being built

15 feet, 18 feet, and 22 feet diameter, by 40 feet, 50 feet, and 60 feet high, according to circumstances; and in America Whitwell's stoves are being constructed 21 feet in diameter and 70 feet high, each stove having 30,900 feet of heating surface. The advantages of these high stoves are increased heating surfaces, more perfect combustion, and reduced number of stoves, consequently reduced space and cost per furnace. The gases enter the large combustion chamber, where they are mixed with hot air, drawn by a new arrangement through the bottom brick-work of the stove. The flame rises to the top of the combustion chamber, then descends three smaller chambers at the same time, where it is mixed with more warm air; it again ascends through two or three chambers at a time, and finally descends the three or four remaining chambers, having been mixed with air at each ascent and descent. It then escapes at the chimney valve at a very low temperature, say from 300° to 400° Fahr. Doors allow access for the scrapers for removing the dust from the walls of the chambers, and other doors, six in number, allow of the dust which has fallen from the walls being readily removed from the bottom of the stove. This scraping and cleaning of the stove need not occupy more than six hours every three or four months, and there is no necessity for cooling down the stove for cleaning, for directly the blast is shut off the operation of cleaning can be immediately commenced. There is a disadvantage in having several firebrick stoves working into one large main flue leading to a single chimney, as it necessitates the stoppage of the whole of the blast furnaces during the time the main flue is being cleaned. Perhaps a better arrangement would be to erect a wrought-iron chimney for each stove, just high enough to convey the waste gases over the heads of the men charging the blast furnaces. The chimney could be secured to the stove itself, and the waste heat is so low that no damage would result to the plates of the chimney.

The united improvements of these hot-air stoves in recent years, and the adjustment of the blast furnace to the largest capacity, consistent with economy, for smelting the ore of Cleveland, have mainly contributed to economy in the use of fuel. In 1860 the consumption of fuel was an average of 38 cwts. of coke, or 63 cwts. of coal per ton of iron, the coal yielding 60 per cent. of coke. As

a matter of general practice, Mr. I. Lowthian Bell * says "that a capacity of 12,500 cubic feet, with air at 1,000° Fahr., is regarded as effecting all that can be hoped for in reducing the coke required for the blast furnace. Other considerations connected with labour, &c., have led many ironmasters to think that a furnace 80 feet high, with a diameter of 25 feet, and containing therefore 25,000 cubic feet, when supplied with air at 1,000 degrees Fahr., is as economical a form as can be devised for smelting the ironstone of Cleveland. The weekly make of a furnace of the above dimensions is said to be 400 tons."

Following the consumption of fuel in the manufacture of pig-iron, the annexed statement gives, for the nine years ending 1880, the pig-iron made and the coal and ironstone used in its manufacture :—

Year.	Pig-Iron Made.	Coal Used.	Ore Used.
	Tons.	Tons.	Tons.
1872	1,122,114	2,533,781	3,493,000
1873	1,156,431	2,643,997	3,489,383
1874	1,158,471	2,896,177	3,504,660
1875	1,240,243	2,875,357	3,740,300
1876	1,261,013	2,923,870	3,807,800
1877	1,374,582	3,220,616	4,339,907
1878	1,358,442	2,934,634	4,234,017
1879	1,210,091	2,589,660	3,699,108
1880	1,666,156	3,611,543	5,044,420

An analysis of these figures shows that in 1872 and 1873 each ton of pig-iron consumed 46 cwts. of coal; in 1876 and 1877 it was slightly above this average, while in 1878 and 1879 the average was about 41¾ and 42¾ cwts. of coal respectively to each ton of pig-iron made. In 1872 the average of the kingdom was 51 cwts. of coal to each ton of iron made, compared with 44 cwts. in the year 1880, showing economy to the extent of 7 cwts. of coal to each ton of iron made, equivalent to a saving of nearly 14 per cent. in a period of nine years.

The average amount of metallic iron in the ores of Cleveland is about 30 per cent., and where the ore alone is employed 70 cwts. of raw stone is required to each ton of pig-iron. The ironstone is previously calcined in suitable kilns—the mineral

* "Notes on the Progress of the Iron Trade."—*The Iron and Coal Trade Review* June 7th, 1878.

being thus concentrated, 100 tons of raw stone yielding on calcination from 70 to 75 per cent. of metal, and even more. In the calcination of the ironstone, in Gjer's calcining kilns, largely employed in the district, having a capacity of 5,500 cubic feet, about one ton of coal slack is required for each 20 tons of ironstone, while in kilns of larger capacity the consumption of fuel is reduced to one ton per 25 tons of ironstone.

As previously stated, 70 cwts. of raw Cleveland stone is required for each ton of pig-iron made; considerable quantities of richer ores are, however, employed; these are the hematites of the west coast, and of Spain, containing from 50 to 60 per cent., and even more, of metallic iron, which, when used in admixture with the Cleveland stone, greatly diminishes the quantity of ore employed in making each ton of iron, which does not exceed from 60 to 62 cwts.

Referring to the question of fuel and ore used in the Cleveland furnaces, it only remains to add that the coke employed is obtained from the Durham coal-field, the iron ore employed, as already stated, being derived from various localities; the great bulk being obtained in the district.

Of the iron ore thus employed, the statement below, prepared from numerous sources, will show approximately the quantities used, and from whence derived, in each year since 1872:—

Year.	Cleveland Ironstone.	Cumberland Ore.	Lancashire Ore.	Foreign Ore.	Other Ores.	Total Iron Ore used.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1872	2,955,000	32,498	17,502	58,000	430,000	3,493,000
1873	2,920,000	32,629	30,250	64,280	442,224	3,489,383
1874	2,980,500	57,668	11,210	49,379	404,903	3,504,660
1875	3,296,824	32,438	10,000	27,523	373,515	3,740,300
1876	3,524,962	38,736	21,600	94,269	108,233	3,807,800
1877	3,980,770	40,087	25,945	133,562	159,543	4,339,907
1878	3,850,045	37,578	25,430	178,982	135,982	4,234,017
1879	3,380,015	37,896	31,694	112,247	137,256	3,699,108
1880	4,463,229	35,298	22,646	430,212	93,035	5,044,420

The quantities in the column "other ores" include ores from various localities, Cornwall, Devonshire, &c.; also forge and mill cinder from the malleable-iron works and "purple ore."

Malleable Ironworks and Steelworks.—The Middlesborough Bar Ironworks were projected by the Messrs. Bolckow & Vaughan about the year 1840, and twenty years later consisted of

70 puddling furnaces and 6 rolling mills. In the year 1852 these works turned out no less than 56,000 tons of plate, rails, and other kinds of finished iron, including angle-iron of all sizes. In 1860 the works and their resources were as follows, giving an aggregate of 116 puddling furnaces and 16 rolling mills:—

Name of Works.	Name of Firm.	Number of Puddling Furnaces.	Number of Rolling Mills.
Middlesbro' . .	Bolckow & Vaughan .	70	6
Tees	Gilkes, Wilson, Pease & Co. . .	5	6
Tees Side . .	Hopkins & Co. . .	41	4
	Total. . .	116	16

Recently, in the pages of the *Colliery Guardian*,* appeared an interesting account of the finished iron trade of Cleveland, from which many of the following facts and figures are drawn. The puddling furnace and the rolling mill inevitably followed in the train of the blast furnace, and as the number of the latter multiplied so also did the former increase. During the decade 1860—1870 the height and economy of the blast furnace was the all-absorbing question in the district, and after came that of mechanical puddling. In 1870 there were 20 works in Durham and 11 in Cleveland, with a total of 1,582 puddling furnaces and 97 rolling mills, of which 529 puddling furnaces and 30 rolling mills were in Cleveland, the remainder being in Durham, giving an average of 51 puddling furnaces and 3 rolling mills to each concern.

The works and firms in operation in 1870 were as follows:—

Name of Works.	Name of Firm.	Situate.	Puddling Furnaces.	Rolling Mills.
			Nos.	Nos.
North Yorkshire .	North Yorkshire Iron Co., Lim. .	Middlesbro'	58	1
Cleveland . .	Bolckow & Vaughan . . .	"		
Middlesbro' . .	" " . . .	"	175	8
Witton Park .	" " . . .	"		
Tees Side . .	Hopkins, Gilkes & Co., Limited .	"	102	5
Newport . .	Fox, Head & Co.	Stockton	54	2
Stockton . .	Stockton Malleable Iron Co. .	"	56	5
Thornaby . .	William Whitwell & Co. . .	"	31	3
Yorkshire . .	Richardson, Dack & Co. . .	"	9	2
Westbourne .	John Holdsworth & Co. . . .	"	21	1
West Stockton .	West Stockton Iron Co. . .	"	23	3
	Total of District. . .	. .	529	30

* 17th December, 1880, p. 971.

About this time, and until 1873, trade was in a buoyant state, but the resources for manufacture also increased, several new works being projected; however, towards the close of the last-named year prices began to decline, and this told heavily upon the department of trade in the district; indeed, no other department and no other district felt it so heavily. Towards the close of 1879 only one-half of the works for the manufacture of finished iron were in operation. Of the works in this district and Durham 22 were standing in 1879, representing a total of 1,328 puddling furnaces, and in October, 1879, Mr. Wm. Whitwell gave the following as the condition of these furnaces:—

	FURNACES.
Failed and not since restarted	821
Pulled down for steelworks	67
Standing possibly temporarily	432
Working	830
Total furnaces	2,150

The depression in the finished iron trade was decisively shown in 1876, when there was a great falling off in the production. In 1877 this was made manifest by a decrease in the number of works employed in that department of the trade. Not the least remarkable feature of the trade is the fact that the production of finished iron decreased while that of pig-iron increased.

There is no means of ascertaining correctly the quantity of finished iron made annually, statistics not being collected in this branch of the iron trade. There is, however, one reliable source of information. Since the year 1872 the firms on the north-east coast, that are associated with the Board of Arbitration for the district under review, have given annual returns of their production. It is believed that between the years 1872 and 1877 the firms in association produced nine-tenths of the total finished iron in the district, but since 1877, owing to some large firms having withdrawn from that board, the statistics issued under its auspices are said now to represent only three-fourths of the total production.

From the returns of the Board of Arbitration, in each of the following years, will be seen the proportion of the several varieties of finished iron, and the fluctuations to which each of these branches of the trade has been subject:—

Year.	Rails.	Plates.	Bars.	Angles.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
1872	330,000	194,857	82,653	63,967	671,477
1873	356,884	182,151	87,368	48,843	675,246
1874	291,520	196,099	100,157	54,450	642,226
1875	270,828	190,757	111,800	45,369	618,754
1876	118,615	189,611	97,133	57,930	463,289
1877	40,425	236,195	84,844	73,738	435,202
1878	25,973	280,754	93,937	105,178	505,842
1879	8,460	217,121	76,848	61,114	363,543
1880	27,414	316,720	71,377	92,897	508,434

The branch of the finished iron trade that has shown the greatest diminution is the manufacture of iron rails, and Mr. Edw. Williams, President of the Iron and Steel Institute, explained the cause of the decay of the industry clearly in a recent address, when he said: "That for rail making the puddling forge has disappeared, and it is highly improbable that it will return. The place of it has been entirely taken by the Bessemer pit, which, in principle, general arrangement, and the most minute details, remains as it came from the hands of the inventor, and seems scarcely to admit of much improvement.

"If it be true that iron rails are doomed to ultimate disuse, it is no less true that the present year has witnessed the beginning, in Cleveland, of the manufacture of steel rails from its own native iron, the cheapest in the world. The basis of a new industry has been laid in this department of the trade under the most favourable auspices. The firm of Messrs. Bolckow & Vaughan, who were the pioneers of the Cleveland iron trade, and who now produce one-third of the total quantity of the iron produced in the district, have also taken the lead in the establishment of steel works. In the year 1877 they opened the Eston Steelworks, which had been about eighteen months in course of construction. They were started especially for the manufacture of steel rails, and for that purpose Spanish hematite was imported in considerable quantities. Since then the discovery of the basic process of dephosphorisation last year, and its successful application more recently at the above-named works, will probably prove the commencement of a new and more promising era in the history of the finished iron trade of Cleveland."

The successful issue of the experiments made in this direction

are thus referred to by Mr. E. W. Richards, in his address to the Institution of Cleveland Engineers, in November, 1880.

The Thomas-Gilchrist Process.—He said: "A short history and description of a process which has created so much interest in the metallurgical world during the last two years will no doubt be of interest to you. Messrs. Thomas and Gilchrist made numerous experiments on a small scale at the Blaenavon Iron-works, where they were assisted by the manager, Mr. Edward P. Martin, and they tried also a couple of casts in a large converter at Dowlais. They prepared a paper, giving very fully the results of their experiments, with analyses, which was intended to be read at the autumn meeting of the Iron and Steel Institute in Paris in 1878; but so little importance was attached to it, and so little was it believed in, that the paper was scarcely noticed, and it was left unread till the spring meeting in London in 1879. Mr. Sidney Thomas first drew my particular attention to the subject at Creusot, and we had a meeting a few days later in Paris to discuss it, when I resolved to take up the matter, provided I received the consent of my directors. The consent was given, and on the 2nd of October, 1878, accompanied by Mr. Stead, of Middlesborough, I went with Mr. Thomas to Blaenavon. Arrived there, Mr. Gilchrist and Mr. Martin showed me three casts in a miniature cupola, and I saw sufficient to convince me that iron could be dephosphorised at a high temperature. I visited the Dowlais Works, where Mr. Menelaus informed me that the experiments with the large converter had failed, owing to the lining being washed out. We very quickly erected a pair of 30 cwt. converters at Middlesborough, but were unable for a long time to try the process, owing to the difficulties experienced in making basic bricks for lining the converter and making the basic bottom. The difficulties arose principally from the enormous shrinkage of the magnesian limestone when being burnt in a kiln with an up-draught, and of the failure of the ordinary bricks of the kiln to withstand the very high temperature necessary for efficient burning. The difficulties were, however, one by one surmounted, and at last we lined up the converters with basic bricks, when, after much labour, many failures, disappointments, and discouragements, we were able to show some of the leading gentlemen of Middlesborough two successful operations on Friday, April 4th, 1879. The news of this success spread

rapidly far and wide, and Middlesborough was soon besieged by the combined forces of Belgium, France, Prussia, Austria, and America. We then lined up one of the 6-ton converters at Eston, and had fair success. The next meeting of the Iron and Steel Institute in London, under the presidency of Mr. Edward Williams, was perhaps the most brilliant and interesting ever held by the Institute. Messrs. Thomas and Gilchrist's paper was read, and the explanations and discussions by other members of the Institute were listened to with marked attention. Directly the meeting was over, Middlesborough was again besieged by a large array of Continental metallurgists, and a few hundred-weights of samples of basic bricks, molten metal used, and steel produced were taken away for searching analysis at home. Our Continental friends were of an inquisitive turn of mind, and, like many other practical men who saw the process in operation, only believed in what they saw with their own eyes and felt with their own hands—and were not quite sure then, and some are not quite sure even now. We gave them samples of the metal out of the very nose of the converter. Our method of working at that time was to charge the additions of oxide of iron and lime at the same time into the converter, and pour the molten metal upon them. The quantity of additions varied from 15 to 25 per cent. on the metal charged, according to the amount of silicon in the pig-iron used. We soon found that the oxide of iron was unnecessary; besides, it cooled the bath of metal, and we afterwards used lime additions only. After about three minutes under blow, a sample of metal was taken from the converter, quickly flattened down under a steam hammer, and cooled in water. The fracture gave clear indications of the malleability of the iron. When the bath was sufficiently dephosphorised to give a soft ductile metal, the spiegel was added. Other firms have taken up the manufacture of steel on the basic system, notably the Hoerde Company, in Westphalia, and Messrs. Brown, Bayley & Dixon, of Sheffield. Very interesting papers on the subject have been read by Messrs. Pink and Messenez and Messrs. Holland and Cooper. On Monday, the 23rd of August last, I visited the Hoerde Works with a few friends, and saw two successful casts in a small converter. Imitating the good example set me, and having good friends in Messrs. Messenez and Pink, I took a sample of the re-melted pig as it was running from the cupola to the converter,

and a sample of dephosphorised metal and of the steel. Mr. Cook's analysis is: Re-melted pig—Combined carbon, 2·75; manganese, ·50; silicon, ·9; sulphur, ·31; phosphorus, 1·51. This analysis agrees with that given by Mr. Messenez in his paper read before the Institute. The metal, after three minutes' after-blow, gave phosphorus, ·13, and a further 25 seconds gave phosphorus ·10; carbon, a trace; manganese, ·17; sulphur, ·12. At this stage of the operation a large quantity of slag was poured out of the converter, and then the spiegel was added. The steel contained carbon, ·19; manganese, ·57; sulphur, ·10; phosphorus, ·10. The steel worked well under the steam hammer. The slag was of the following composition:—Iron, 10·20; lime, 46·94; silica, 9·67; phosphoric acid, 9·70. On Thursday, the 20th August, I visited the Rhenish Steelworks with several members of the Iron and Steel Institute, and the samples brought home were analysed by Mr. Cook, who shows re-melted metal to contain—Combined carbon, 2·90; manganese, 1·10; silicon, ·46; sulphur, ·16; phosphorus, 2·03. The after-blow was very long, being nearly 4¼ minutes before the first sample was taken, and a further three-quarters of a minute before the second sample was taken—in all five minutes. The carbon lines appeared on the spectroscope in a few seconds after the converter was turned up. The steel contained:—Carbon, ·28; manganese, ·56; sulphur, ·08; phosphorus, ·08—the metal, before the addition of the spiegel, having P, ·07. In a second cast the steel gave—C, ·27; M, ·40; S, ·07; P, ·10. The slag here is not passed off before the spiegel is added. The sample of slag analysed by Mr. Cook is almost identically the same as that given above from the Hoerde Works. Another cast, made when about 150 members of the Institute were present, contained, I am informed, P, ·13. It was most difficult to get near the workmen who were testing the samples, so great was the crush and the desire to obtain a piece of metal, and the wonder was that the metal was so well blown and so low in phosphorus, considering the circumstances under which the operation was conducted. At the meetings of the Institution in December last I mentioned that Messrs. Bolckow, Vaughan & Co., Limited, were about to erect some large converters at the Cleveland Steelworks of a size and form which they expected would enable them to overcome some of the difficulties which they experienced when working with the old converters on the basic system."

Mr. Richards next directed attention to a new converter; continuing, he said: "This converter is concentric, whilst the old converters are eccentric. During the operation of blowing, the lime and the metal are lifted by the force of the blast, and when that force is somewhat expended the materials fall again on to the bottom in the new form, whilst in the old form some portions would cling to the nose. The 'concentric' form has also another advantage; it gives a much larger area of floor to work in, by enabling the metal to be poured into the converter when turned on its side with the nose pointing away from the converter ladle crane, just the contrary of the present practice. On the 18th October last this converter was set to work on the basic system, and was quite successful, answering the purpose well, and showing no more symptoms of gathering at the outlet than when making ordinary steel. Our plan of operation is exceedingly simple. The converter, as is usual, is first heated up with coke so as to prevent the chilling of the metal. Then a measured quantity of well-burnt lime, about 16 per cent. of the weight of molten metal, mixed with a small quantity of coal or coke, is charged into the converter, and blown till the lime is well heated. The molten metal is then poured on the lime additions, the blast of 25 lbs. pressure is turned on, and the carbon lines disappear in about ten minutes; then after about 2½ minutes over-blow the converter is turned down, and a small sample just made, which is quickly beaten into a thin sheet under a small steam hammer, cooled in water, broken in two pieces, and the fracture shows to the experienced eye whether the metal is sufficiently ductile. If it is not so, then the blowing is prolonged, after which the spiegel is added, and is now being poured into the ladle, not into the converter. For the basic process the initial bath should be low in silicon, because silicon fluxes and destroys the lining, and causes waste of metal; it should be low in sulphur, so that the metal may not be red short. Nearly one-half the sulphur is eliminated by the basic process. In order to work economically the metal should be taken direct from the blast furnace, so as to avoid, first, the cost of re-melting in a cupola; and, second, to avoid further contact of the metal with the sulphur and impurities of the coke. It is not an easy matter to accomplish, in a blast furnace, the manufacture of a metal low in silicon and at the same time low in sulphur. It would, no doubt, very much help to

keep sulphur low if maganese was added in the blast furnace, but maganese is a costly metal. At present we have succeeded in making a mottled Cleveland iron with 1 per cent. of silicon and ·16 sulphur, and white iron with ·5 silicon and ·25 sulphur, which, taken direct from the blast furnace, have both made excellent steel. But we have another method of operating, which relieves us from the necessity of making a particular quality of Cleveland pig-iron. We call this second mode of working the transfer system, because we transfer the metal from the acid to the basic converter. The transfer system enables us to take any grey iron direct from the blast furnace to the converter without any consideration as to the per centage of sulphur, which is always low in grey iron. This grey metal is poured into a converter with a silicious lining, and desiliconised, when, after say twelve or fifteen minutes' blowing in the ordinary manner, it is poured out of the converter into the ladle, and poured again from the ladle into a converter lined with dolomite, taking care that the highly silicious slag is prevented from entering the basic-lined converter. Then in the second converter it is only necessary to add sufficient lime for the absorption of the phosphorus of the metal, and the blowing then need not occupy more time than is necessary for the elimination of the phosphorus, say about three minutes. This mode of operation will no doubt give the basic lining and bottom a much longer life, but we have not yet been long enough at work to obtain the necessary experience to determine which is the better system of working, but both are good and effective, and have given excellent results. I have thus summed up in ten minutes what has taken about two years of constant work, and the expenditure of large sums of money, to accomplish. I am now able to say that the basic process has been brought to a technical and commercial success at the Cleveland Steelworks of Messrs. Bolckow, Vaughan & Co. One feature in this new process seems to have been lost sight of by those who have written on the subject, namely, the possibility or otherwise of being able to eliminate phosphorus before the carbon flame drops so as to avoid the after-blow. Few give any hope of this being accomplished, but when we remember that few gave any hope of the basic process, or any other process, being successful in eliminating phosphorus at the high temperature of the Bessemer converter, we should not abandon research or relax efforts. It

has been said, over and over again, that the basic process was a failure, and would never succeed. It is a grand trait in the character of our Englishmen, that of not knowing when they are beaten. If the after-blow could be avoided, the wear of the lining and bottoms would be very much reduced. We know already that the basic lining will not be anything like so enduring as the acid lining, so special means have been adopted to quickly change a converter. An overhead steam-travelling crane, capable of lifting sixty tons, is being erected, so that directly a converter lining has worn out the crane will remove the worn converter out of the way, and bring in a re-lined one dried and ready for working. A very ingenious plan for quickly changing the converter, without removing the trunnion, is that patented by Mr. Holley, the well-known American engineer and metallurgist. The converter, freed from the trunnion, is lowered to the floor by means of the hydraulic ram. Then a re-lined and dried converter is placed on a four-wheeled bogie, and ran from the repairing and drying shed into position on the top of the hydraulic ram, which is placed directly under the trunnion. The water is turned on, and the converter is raised into position, and is then fastened by a dozen cotters to the trunnion, and is thus got very quickly ready for work."

The following is a list of the malleable-iron works in Cleveland in 1880, with the number of furnaces and mills in operation :—

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Ayrton Rolling Mills	Jones Bros. & Co., Lim.	Stockton-on-Tees	29	2
2	Bowesfield	Bowesfield Iron Co.	"	33	3
3	Britannia	Dorman, Long & Co.	Middlesbro'	60	1
4	Erimus	Erimus Iron Co., Lim.	"	..	..
5	Eston Grange	Eston Grange Iron Co.	"	..	..
6	North Yorkshire	North Yorkshire Iron Co., Limited	Stockton-on-Tees	..	..
7	Carlton	The Carlton Iron Co., Lim.	"	..	..
8	Cleveland	Bolckow & Vaughan	"	..	3
9	Middlesbro'	" "	"	..	1
10	Tees Side	Hopkins, Gilkes & Co., Limited. 11 Danks's	"	80	4
11	Newport	Fox, Head & Co.	"	46	4
12	Yorkshire	South Yorkshire Iron Co., Limited	"	..	..
13	Westbourne	John Holdsworth & Co.	"	22	2
14	West Marsh	Dorman, Long & Co.	"	20	2
15	Hull	East Riding Malleable Ironworks	Hull	..	..
16	Imperial (South Bank)	Jackson, Gill & Co., Lim.	. . . . .	38	3
17	Star	Star Rolling Mills Co.	Middlesbro'	..	..
	Total of District	. . . .	. . . . .	328	25

Considering the consumption of fuel in these works, it was ascertained that in the year 1872 some 640,000 tons of coal were used, increased to 660,000 tons in the following year; since that date the fuel consumed annually in these works in Cleveland has fallen off considerably, and in the year 1879 did not exceed 405,000 tons. It has been observed that when the manufacture of iron rails in Cleveland saw its best days, that district produced, it is estimated, nearly one-third of the rails made in the United Kingdom. The success which has attended the process of dephosphorising Cleveland iron brings it within the bounds of possibility that that district may before long occupy as prominent a position in the manufacture of steel rails as of old it held in the iron rail trade. Already the leading firm is reported to be producing steel at the rate of 150,000 tons per annum, nearly double the total quantity produced last year in the whole district, and if that is mostly made into rails, the revival of that industry is as rapid as was the decline of the iron rail trade.

Prices of Malleable Iron and Puddlers' Wages.—These have been subject to great fluctuations; the average prices of rails, plates, bars, and angles, in 1879, were about one-half of the prices current in 1873, and wages showed a corresponding fluctuation. From the Board of Arbitration returns in each year since 1872 the average selling prices of iron, including rails, plates, angles, and bars, were as follows; and side by side appears the average puddlers' wages, in each of the same years:—

Year.	Average Selling Price.			Average Puddlers' Wages	
	£	s.	d.	s.	d.
1872	9	0	3	11	6
1873	11	9	1	13	0
1874	10	9	5	11	7
1875	8	1	0	9	4
1876	7	2	2	8	3
1877	6	15	3	8	3
1878	6	2	7	7	8
1879	5	8	6	7	0
1880	6	3	9	7	9

The highest price reached was in the year 1873, when puddlers' wages were 13*s.* 3*d.* during nine months of that year.

Prices fell in the following year, and wages increased somewhat. The rate of wages changed four times in 1874, and three times in 1875. During 1876 and 1877 it remained stationary, since which, in 1878 and 1879, the tendency was downwards. However, in the first half of 1880 the wages of puddlers gave an average of 8*s*. 3*d*., while the realised prices per ton fell to £5 5*s*. 6*d*.

Following the prices of each variety of iron since the year 1872, the annexed statement, based upon the returns of the Board of Arbitration, will indicate those of plates, bars, and angles, which were as follows:—

Year.	Plates. Average.			Bars. Average.			Angles. Average.		
	£	s.	d.	£	s.	d.	£	s.	d.
1872	10	6	1	9	16	4	9	1	11
1873	12	6	1	12	5	3	11	11	1
1874	11	6	4	10	15	7	10	11	10
1875	8	14	9	8	9	8	8	3	6
1876	7	9	9	7	1	8	7	0	4
1877	6	19	8	6	16	2	6	8	1
1878	6	6	9	6	4	6	5	13	2
1879	5	10	10	5	8	11	5	1	3
1880	6	9	5	6	7	9	5	14	9

From the annual Report of the British Iron Trade Association, for the year 1879, some very interesting facts are obtained, showing the average prices, in each of the above years, of iron rails, as compared with steel rails, the former being, in 1872, £9 6*s*. per ton, compared with £4 18*s*. 3*d*. in 1879; while steel rails were, in 1872, current at £13 17*s*. 6*d*. per ton against £5 2*s*. 6*d*. per ton in 1879. The average prices are as follows:—

Year.	Price of Iron Rails.			Price of Steel Rails.			Difference.		
	£	s.	d.	£	s.	d.	£	s.	d.
1872	9	6	0	13	17	6	4	11	6
1873	11	4	4	15	10	0	4	5	8
1874	8	9	0	9	17	6	1	8	6
1875	6	19	6	8	7	6	1	8	0
1876	6	0	10	7	2	6	1	1	6
1877	5	15	3	6	7	6	0	12	3
1878	5	2	1	5	12	6	0	9	11
1879	4	18	3	5	2	6	0	4	3
1880	6	3	4	7	7	6	1	4	2

CHAPTER IV.

CUMBERLAND IRON INDUSTRIES.

Description of Iron Ore Deposits around Whitehaven—Alston Moor—Eskdale and Millom—Analyses, production and distribution of Ore—Population employed in Iron Ore Mining—List of Iron Mines—Pig-Iron Manufacture—Charcoal Furnaces, their Early History—Steelworks—Ironworks—Pig-Iron made—Coal and Ore used in Manufacture—Works in 1880—Malleable-Iron Works and Coal employed.

Iron Ore of the Carboniferous Limestone.—By far the largest proportion of the Cumberland hematite occurs in the Carboniferous or Mountain Limestone. Around Whitehaven, where the carboniferous formation is well developed, it consists in its lowest part of about 250 feet of massive limestone, in immediate contact with that division of the Lower Silurian system known as the Skiddaw Slates. Above this massive limestone are a number of thin beds of limestone, shale, and sandstone or "Whirlstone," making together a series of about 150 feet thick; these beds are followed by a succession of sandstones and shales varying in thickness from 180 to 300 feet. The hematite occurs chiefly on two horizons, one in the lower massive limestone and the other in the thin beds of limestone and shale. Although the ore is often found in large irregular deposits in the limestone, and occasionally in the form of fissures, it is more commonly spread out in the shape of flat deposits, following more or less closely the general dip of the beds, this inclination being usually about 12° or 18° to the west, or filling caverns in the limestone. In thickness the ore deposits vary from 30 feet to 100 feet and upwards; a deposit sometimes suddenly enlarges or diminishes in thickness, thus producing what the miners call "rolls"; the deposits are frequently cut off by faults. In some cases, as in the Cleator Mines, the body of ore is divided into distinct masses by pillars of rock extending from sole to roof. The roof is generally hard, and consequently large excavations are rendered

possible without much artificial support. Although the forms of the deposits are very irregular, it has been remarked that they correspond in their extension with the direction of the magnetic meridian, but this has no relation to the run of the deposits. Some of the deposits of ore occupy a large superficial area; that at Parkside, for example, and the adjoining mines, where the deposit was above 70 feet thick, extending over about 60 acres.

At the mines of the Crossfield Iron Ore Company near Whitehaven, the iron ore is found in the mountain limestone, in faults or dislocations, running north and south, although it is also found lying in irregular masses and preserving a marked parallelism, with a bearing of about 12° N.W.

The distribution of the ore deposits is very irregular, and their existence is only determined by borings, which have to be made almost at random. In the Whitehaven district the ore is distributed over an area extending about eight miles, from south-west to north-east, with an average width of one mile. At Millom the ore-bearing limestone occupies an area of only about one and a half square miles, or between 900 and 1,000 acres.

In addition to the deposits of the mountain limestone, there are veins of hematite in the Lower Silurian rocks of Cumberland; in some cases these occur in the Skiddaw slates, as at Kelton and Knockmurton; in others, in the series of green slates, as at Dunnerdale; and in others again, in the Coniston limestone, as at Waterblean. Nor should mention be omitted of veins of hematite in the granite of Eskdale. For the most part these veins in the older rocks have a general north and south trend, with a dip varying in direction and degree; whilst in thickness the ore, though often but a few inches, may reach as much as 12 or 14 feet. The geological position of the Cumberland hematites has been well described by Mr. P. Wurzburger, of Dalton in Furness, and by Mr. J. D. Kendall, from whose valuable papers the foregoing facts have been gathered.

The iron ore of Cumberland is exclusively of that kind which is known mineralogically as red hematite; it is chemically an anhydrous peroxide of iron (ferric oxide), containing about 70 per cent. of iron, but the ore is, of course, rarely, if ever, found in a state of chemical purity. Most of the Cumberland hematite is of the hard variety known as "blast ore," although in some places, as at Kelton and the adjoining mines, the soft varieties are

found. The hard hematite occasionally occurs in masses presenting a finely lobed surface, whence the name "Kidney ore;" whilst, in rare cases, brilliant lenticular crystals of "specular iron ore" have been found. Associated with the hematite the following minerals occur:—quartz, calcspar, brown spar, heavy spar, peroxide of manganese, and iron pyrites. The red hematites of Whitehaven, in Cumberland, and Ulverstone, in Lancashire, are by far the richest raised in the United Kingdom. The ore, since the introduction of the Bessemer process, has been in great demand, from the high character and purity of the pig iron produced from it, and it is largely exported into other iron-making districts in the kingdom, where it is extensively employed in admixture with other ores, giving an improved quality of iron. Brown hematite has, from time to time, been wrought at Alston Moor and at Nenthead, in the limestone at Kilhope Fell. This limestone bed corresponds with the Fell Top limestone of the district, which, in this locality, becomes ferruginous, probably owing to its being intersected by a considerable number of small veins carrying iron "riders." The brown hematite ore occurring in this limestone varies from 3 to 7 feet thick, and is of good quality. At Nenthead, in the little limestone of the district, a bed of brown hematite occurs, about 7 feet in thickness; the quality of the ore, however, is very variable. Similar ore is met with in the Silly Hole, Manor House, and Nenthead veins of Alston Moor.

In Eskdale, some seven miles from the terminus of the Ravenglass and Eskdale Railway, in the Manor of Birker, at Ore Gap, some lodes of brown hematite are known to occur. The district was examined a few years since by Mr. Robert Woodley, of the Birker Moor Iron Mines, who reports as follows: "That in Yeasty Rigg Gill, out of Green Hole Glen, 1,400 feet above the level of the sea, there are two large and powerful hematite lodes in the Ash rocks and felstone, one on each side of the Gill. On the west slope, the first lode, some 50 feet wide, is visible at the surface, and can be traced by outcrop and excavations for about three-quarters of a mile through Ore Gap to the Keswick side of the mountain. It takes a course a few degrees west of south. The second lode, on the eastern slope of the Gill, is equally large, and bears a little west of north, forming a junction with the first lode in the Gill, whence they pass together

through a wide gap in the Fell, very appropriately called Ore Gap, which is 2,600 feet above the sea level, and situated between Bow Fell and Sea Fell Pikes."

"In this gap the united lodes have thrown up to the surface a curious back of hematite of the finest quality, composed of hard blue, kidney and puddle ore many fathoms in width and at least 300 fathoms in length from the junction of the lodes. A deep trench has been driven across this magnificent deposit, and pits have been opened on either side of it, showing the beds of hard ore embedded with the soft decomposed hematite. As the lodes forming this deposit are traceable in the glen called "Green Holes," at a level 1,200 feet below Ore Gap, the cubic contents of this deposit must be reckoned by millions of tons; for a deposit only 100 fathoms in length by 20 fathoms in breadth would yield 500,000 tons for every 10 fathoms in depth, reckoning only 3 tons of ore to each cubic yard. And the upper part of this deposit can be worked on the most extensive scale by open cutting, and broken and loaded into trucks, and sent by a self-acting incline to the foot of the mountain in Green Holes, at a cost not exceeding 2*s.* 6*d.* per ton. About 100 fathoms on the east side of this deposit a great lode of 20 or 30 feet in width, enters the mountain through a great fissure above Angle Tarn, and throws up to the surface another bank of hard blue hematite. This lode, which bears a little east of north, forms a junction with the two first named lodes about the middle of Yeasty Rigg Gill. A fourth lode, coming from the Rest Gill, and bearing south of east, forms a junction with the two largest lodes at the southern end of Yeasty Rigg Gill, where its broad red back is visible, showing every appearance of being rich in iron. This can be worked with the greatest facility by a series of levels driven into the fell just above Green Holes, whence also as many as twenty levels can be driven into the above-mentioned lodes below the surface-workings."

Another interesting feature in Mr. Woodley's report of the Eskdale district, comprises a recommendation for the development of the iron ore deposits by a line of railway through the fell land to connect with the Ravenglass and Eskdale line.

Analyses of the Cumberland Ore.—The hematite of the Whitehaven district, as previously stated, occurs in the carboniferous limestone, near the outcrop or surface of the slaty

rocks upon which that formation rests. The ores raised at Cleator Moor, rich in metallic iron and valuable for the manufacture of steel, are thus described * by Mr. A. Dick:—

"Compact red hematite; easily scratched by a file; lustre, earthy; colour, purplish grey; streak, bright red; fracture, uneven; containing cavities lined with crystals of specular iron, and containing, in some cases, quartz."

The first analysis consisted of a sample composed of a mixture of the above ore and of another variety, thus described, resembling the former: "It is harder, being scarcely scratched by a file, more lustrous and darker in colour, the cavities contain more quartz, but the substance of the ore seems purer." The second analysis, given also of hematite from Cleator Moor, is very similar in character, but does not contain quartz visibly diffused through it. The sample examined is also a mixture of varieties, the one compact, the other unctuous, more lustrous, and redder in colour than the compact variety. The constituents of the two samples are as follows:—

RESULTS TABULATED—ORE DRIED ABOVE 100° C.

Constituents.	No. 1.	No. 2.
Peroxide of iron	95·16	90·36
Protoxide of manganese . .	0·24	0·10
Alumina	...	0·37
Lime	0·07	0·71
Phosphoric acid	trace	trace
Sulphuric acid	trace	trace
Bisulphide of iron . . .	trace	0·06
Magnesia	...	0·06
Insoluble residue . . .	5·68	8·54
	101·15	100·20

INSOLUBLE RESIDUE.

Silica	5·66	7·05
Alumina (containing a trace of iron)	0·06	1·06
Peroxide of iron . . .	...	0·19
Lime	...	trace
	6·72	8·30

The metallic iron contained in these ores were equivalent to 66·60 and 63·25 per cent. respectively; it being further remarked

* "Iron Ores of Great Britain," Part I., pp. 60, 62. (Out of print.)

that a trace of lead was detected in 400 grains of the first sample of ore and in 500 grains of the second.

The hematite of Eskdale has been examined by Mr. Watson, of Braystones, who gives analysis of a sample from Ore Gap, as follows :—

RESULTS TABULATED.

Peroxide of iron	94·00
Oxide of manganese	1·20
Silica	4·00
Magnesia	trace
Moisture	0·80
	100·00

Production of Iron Ore.—In the year 1849 there appears to have been in the Whitehaven district thirteen mines, producing hematite amounting to 100,000 tons: the details are as follows * :—

Firm.	Number of Mines.	Quantities.
		Tons.
Messrs. Ainsworth & Co. . .	2	30,000
Messrs. Hill & Co. . . .	4	20,000
Mr. John Lindow . . .	3	20,000
Messrs. Tulk & Ley . . .	2	15,000
Messrs. Atwood & Co. . .	2	15,000
Total	13	100,000

The total quantity of iron ore produced from the mines of the United Kingdom in the same year was but 500,000 tons, contributed as follows from the several hematite producing districts :—

District.	Number of Mines.	Quantities.
		Tons.
Lancashire	17	182,000
Cumberland	13	100,000
Forest of Dean	8	95,000
Cornwall, Somerset, and Devon	17	118,000
Isle of Man	2	2,500
Ireland	1	1,500
Scotland	2	1,000
Total	60	500,000

* "Braithwaite Poole, Report to the Directors of the Lancaster and Carlisle Railway on Iron Ore." 1850.

The estimated value of this ore set down at the works of the consumer was not less than 20*s.* per ton.

In subsequent years the returns show a large increase, amounting in 1855 to 200,788 tons; increasing in 1856 to 259,167 tons, and in 1857 to 323,812 tons; the distribution of which was as follows in 1856 and 1857:—

Destination.	1856.	1857.
	Tons.	Tons.
South Wales	124,630	163,354
Staffordshire	26,768	36,758
Scotland	15,865	22,377
Newcastle, &c.	51,470	44,489
France	817	323
Ironworks	39,617	56,511
Total	259,167	323,812

The only ironworks in operation in Cumberland in the year 1857 were those of Seaton, Harrington and Cleator Moor, in which hematite ore alone was employed. The annexed summary gives the output of the mines of Whitehaven and the value of the ore in each year since 1858:—

Year.	Quantities.	Value.
	Tons.	£
1858	331,544	182,349
1859	400,306	220,168
1860	466,851	256,768
1861	472,095	259,650
1862	533,120	306,544
1863	690,083	414,083
1864	784,174	489,008
1865	678,831	441,240
1866	706,505	459,228
1867	709,037	478,600
1868	725,248	489,542
1869	848,974	594,281
1870	1,014,143	760,606
1871	976,874	1,074,561
1872	954,505	1,193,121
1873	1,021,690	1,277,115
1874	901,667	1,115,685
1875	935,360	701,520
1876	1,082,812	806,278
1877	1,081,256	762,656
1878	1,082,924	713,885
1879	933,369	513,586
1880	1,148,246	914,377

The condition and importance of the iron ore industries of Cumberland appear in the relative prices of the ore from time to time. Glancing generally at the above quantities and values in 1858, the figures give an average price of 11*s.* per ton; this average is fairly maintained for a few years. With the prosperity of the iron industries in the year 1870, the values of these ores show a great increase, the average price showing 15*s.* per ton. In succeeding years this is exceeded; thus, in the year 1873, one of great commercial prosperity, these ores realised 25*s.* per ton, receding to 24*s.* 9*d.* in the following year, and to 15*s.* per ton in the year 1875, since which date the same average prices have ruled with little variation until 1880, when an increased value appears.

In the year 1880 the following mines were producing ore, in the quantities and values given, to which is appended the distribution by railway and ship in the same year:—

Name of Mine.	Quantities.		Value.		
	Tons.	Cwts.	£	s.	d.
Bigrigg (Leconfield) Wyndham Pit	14,179	0	10,698	0	0
,, ,, Lady Pit . .	27,846	0	21,000	0	0
Birks (Frizington) . . .	6,192	15	4,334	8	0
Cleator Moor (Leconfield) York Pit	28,287	0	19,700	18	0
,, ,, James Pit	1,514	0	1,060	0	0
Cleator (5 Pits) ,, ...	40,286	0	32,680	10	0
Crossfield (8 Pits)	98,000	0	78,400	0	0
Crossgill (Maryport H. Iron Co.)	16,237	0	12,207	10	0
Dyke Nook	731	0	456	17	0
Egremont	12,738	0	11,782	0	0
Ehen (Egremont) . . .	19,850	0	17,372	10	0
Eskett and Salter	47,567	0	37,053	6	0
Eskett (Eskett Iron Ore Co.) .	45,000	0	38,250	0	0
Eskett (Postlethwaite) . . .	40,192	0	32,153	0	0
Goose Green (Frizington) . .	12,436	0	10,948	0	0
Gillfoot Park (Egremont) . .	72,880	5	58,304	0	0
Gutterley (Maryport Hematite Iron Co.)	6,850	0	5,479	10	0
High House (Frizington) . .	64,978	0	45,484	12	0
Hodbarrow	343,194	0	240,236	0	0
Holebeck and Rattenrow . .	5,957	0	3,872	1	0
Jacktrees No. 3 Pit (Carron Co.) .	3,133	0	2,349	15	0
,, No. 2 Pit (Carron Co.) .	21,534	0	16,150	0	0
Kelton and Knockmurton . .	47,705	18	47,705	0	0
Lonsdale Nos. 2 & 3 (S. & J. Lindow)	6,175	0	4,631	5	0
Longlands (S. & J. Lindow) .	15,616	0	11,712	0	0
Montreal	210,894	0	158,170	10	0
Murton	950	0	712	0	0
Carried forward . . .	1,210,922	18	922,903	12	0

Name of Mine.	Quantities. Tons.	Cwts.	Value. £	s.	d.
Brought forward . . .	1,210,922	18	922,903	12	0
Mowbray	35,660	0	26,745	0	0
Moor Row (Moor Row Mining Co.)	16,638	0	17,955	0	0
,, (Maryport H. Iron Co.)	24,137	0	24,137	0	0
Nabb Gill	7,812	0	5,275	0	0
Park Side (Frizington). . .	11,303	0	8,477	5	0
Park (Bain & Co.)	3,283	0	2,463	0	0
Salter Hall	38,100	0	30,480	0	0
Sir John and Bigrigg (S. & J. Lindow)	13,798	0	10,937	10	0
Scalelands	1,500	0	1,200	0	0
Winder (Frizington) . . .	33,000	0	29,700	0	0
Winder Gill	3,886	0	3,108	0	0
Woodend (Bain & Co.) . . .	45,902	0	34,426	0	0
Whicham (Silcroft)	26,830	0	22,805	0	0
Wyndham (Egremont) . . .	18,669	0	14,001	5	0
Total of Cumberland . .	1,491,440	18	1,154,613	12	0

CUMBERLAND ORE CARRIED BY THE FURNESS RAILWAYS.

	TONS.	TONS.
For shipment at Barrow-in-Furness . .	5,665	
,, Whitehaven	52,504	
		58,169
By rail sent away to Durham, &c.	66,722	
,, to furnaces in district	911,297	
		978,019
Total of Cumberland ore carried		1,036,188

CUMBERLAND ORE SHIPPED FROM WHITEHAVEN.

TO	TONS.
Cardiff	8,859
Newport	21,102
Ditton Brook	790
Runcorn	145
Garston	2,256
Liverpool	338
Bowling	250
Glasgow	272
Swansea	193
Total shipments	34,205
Shipped from other ports	52,692

Iron Ore Deposits at Millom.—Resembling the flat deposits of the Whitehaven district is the large deposit of Hodbarrow Mines near Millom. Overlaid for the greatest part by limestone, it is from east to west about 470 yards long by 170 to 240 yards in width, the thickness of the ore being in the eastern part from 72 to 90 feet. The dip of the deposit is at an angle of 12° to the west. At some distance to the north-west a second deposit is being

explored which is probably connected with the first one, and is, perhaps, of still greater dimensions. The second deposit is overlaid by loose masses of drift. Since the year 1864 the Hodbarrow Mines at Millom have yielded hematite in the following quantities and values :—

Year.	Quantities.	Value.
	Tons.	£
1864	78,993	39,496
1865	117,330	70,397
1866	131,542	78,925
1867	181,504	90,752
1868	201,380	120,828
1869	198,705	139,093
1870	174,943	122,460
1871	207,146	227,860
1872	211,771	264,713
1873	203,791	254,739
1874	201,663	252,078
1875	202,817	152,112
1876	271,098	189,768
1877	270,195	202,645
1878	274,962	185,599
1879	293,637	161,500
1880	343,194	240,236

Cumberland in the year 1878 stood as the second most important iron ore producing district in the kingdom, Cleveland being the first, with a production of 5,605,640 tons of argillaceous carbonate of iron, of the value of £910,739, or an average varying from 3*s*. to 3*s*. 6*d*. per ton of stone at the mines.

In the following summary the total ore produced in Cumberland appears, showing the yield of each district since 1869 :—

CUMBERLAND IRON ORE.

Year.	Whitehaven District.	Hodbarrow District.	Alston Moor and other Mines.	Total.
	Tons.	Tons.	Tons.	Tons.
1869	848,974	198,705	140	1,047,819
1870	1,014,143	174,943	32,217	1,221,303
1871	976,874	207,146	118,683	1,302,703
1872	954,505	211,771	2,000	1,168,276
1873	1,021,690	203,791	4,345	1,229,826
1874	901,667	201,663	16,332	1,119,662
1875	935,360	202,817	9,791	1,147,968
1876	1,082,812	271,098	...	1,353,910
1877	1,081,246	270,195	...	1,351,441
1878	1,082,924	274,963	...	1,357,887
1879	933,369	293,637	...	1,227,006
1880	1,148,246	343,194	...	1,491,440

The hematitic ores of Cumberland have from an early period been extensively raised for shipment to the ironworks of Yorkshire, Staffordshire, and North and South Wales. In quality these ores may be considered as the best in the kingdom, and the supplies which these districts are calculated to produce are very great. The large per centage of metallic iron which they contain, from 60 to 65 per cent. and even more, and their superior quality, enables them to bear the cost of transport to distant places, where the ore is in great request.

The returns of individual mines were not obtainable until the year 1872, since which date the details have been regularly published.* The detail of distribution of the (Whitehaven) Cumberland ore for a few years will show generally its destination:—

Destination.	1868.	1870.	1872.	1874.
	Tons.	Tons.	Tons.	Tons.
South Wales, by ship	162,811	195,659	107,554	113,191†
Staffordshire, Lancashire, North Wales, by ship	26,287	18,401	561	...
Lancashire, Carnforth and Millom	4,108	84,367	113,901	101,321
Scotland, by rail	107,580	107,457	68,489	69,402
,, by ship	31,358	36,993	6,532	...
Newcastle and Middlesborough districts, by rail	141,054	155,433	85,139	63,385
Workington, Maryport, Harrington, and Cleator districts	252,050	414,522	572,329	554,368
Total of Whitehaven ore	725,248	‡1,014,143	954,505	901,667

In subsequent years the distribution of the ore of Whitehaven is obtained from returns furnished by the Whitehaven, Cleator and Egremont Railway Company. This company was amalgamated in 1877 with the London and North-Western Railway, and in June, 1878, became the joint property of it and the Furness Company, from which date it has been worked jointly. The details of distribution in each year appear as follows since 1876:—

* For which see "Mineral Statistics of the United Kingdom," by Robert Hunt, F.R.S.

† This quantity includes all shipments in 1874.

‡ Including 1,311 tons sent to France.

How Distributed.	1876.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.
Whitehaven shipments	167,529	143,061	88,961	71,864	52,692
" Lonsdale Iron Co.	88,392	103,758	95,468	102,003	131,977
Cleator Moor	46,135	37,987	50,192	61,093	70,674
Distington	..	..	..	4,790	43,020
Parton	25,377	3,769	..	2,970	28,557
Harrington	56,858	80,162	80,036	73,594	109,623
Workington	269,520	249,299	271,671	269,153	415,320
Maryport	169,732	252,799	249,746	237,219	229,616
Scotland	146,723	121,013	49,859	19,746	44,548
Carnforth and Furness	73,191	127,187	1,466	883	4,185
Barrow and Millom	..	..	102,845	22,723	74,033
South of Carnforth	24,674	35,072	22,263	30,653	19,713
East Coast, *viâ* Carlisle	48,936	62,709	226	20	..
" *viâ* Penrith	..	..	39,268	4,628	10,431
Total	1,117,067	1,216,816	1,052,001	901,339	1,234,389

In the year 1878 the Hodbarrow ore was distributed as follows: Shipped at the Company's private harbour, 121,914 tons; to Millom Ironworks, 61,539 tons; carried by Furness Railway, 87,069 tons; the remaining 4,440 tons being disposed of locally.

The following presents a complete list of the iron mines of Cumberland, their situation, and the names of the proprietors working the same in the year 1881:—

CUMBERLAND IRON MINES.

Name of Mine.	Situation.	Name of Proprietor or Company.
Birks, 3 Pits	Whitehaven	Joseph Fearon
Bigrigg, Gutterly, Lonsdale, Longlands — 8 Pits	Egremont, Frizington, and Cleator	S. and J. Lindow
Bigrigg, Wyndham Pit, Lady Pit, Cleator Moor, York Pit, Crowgarth	Whitehaven	Lord Leconfield
Cleator, 4 Pits	"	Cleator Iron Ore Co.
Crossfield, 8 Pits	"	Crossfield Iron Ore Co.
Montreal	"	John Stirling
Dyke Nook	Frizington	Dyke Nook Mining Co.
High House, 4 Pits	St. Bees, Carnforth	Fletcher & Hodgetts
Crossgill	Frizington	Samuel Wagstaff Smith
Egremont	Whitehaven	Egremont Iron Ore Co.
Ehen	Egremont	Ehen Mining Co.
Eskdale	Ravenglass	Whitehaven Iron Mines Co., Limited

CUMBERLAND IRON MINES—*continued.*

Name of Mine.	Situation.	Name of Proprietor or Company.
Eskett, 3 Pits	Whitehaven	Eskett Iron Ore Co.
Salter and Eskett, 3 Pits	,,	Salter and Eskett Park Mining Co.
Eskett, Postlethwaite	,,	J. Postlethwaite, junr.
Frizington Parks, 2 Pits	Frizington	James Bain & Co.
Goose Green	,,	,, ,,
Woodend	Egremont	,, ,,
Hodbarrow, 7 Pits	Holborn Hill	The Hodbarrow Mining Co.
Holebeck and Batten-row	,,	The Dalmellington Iron Co.
Kelton	Lamplugh	W. David & Co.
Millom	Millom	George J. Eveson
Winder	Frizington	Winder Iron Ore Co.
Mowbray, 1 Pit	,,	Mowbray Iron Ore Co., Limited
Moor Row	Moor Row, Whitehaven	Moor Row Mining Co.
Nabb Gill	Eskdale	Whitehaven Iron Mining Co.
New Parkside	Whitehaven	New Parkside Iron Mining Co., Limited
Parkside, 7 Pits	,,	The Parkside Iron Mining Co.
Salter Hall	Cleator Moor	Thos. Dixon & Co.
Steel End	,,	Steel End Mining Co.
Waterblean, 1 Pit	Green Roads, Millom	G. J. Eveson
Winder	Millom	—
Windergill	Winder	Maryport Hematite Iron Co.
Wyndham	Egremont	Wyndham Mining Co., Limited
Yeathouse	Whitehaven	Yeathouse Mining Co.

Population employed in Iron Mines in Cumberland.—The coal-field of Cumberland is barren of those argillaceous ores of iron which are found so abundantly in Staffordshire and other coal-fields, a very thin band only being found near the Parkside Mine. On the other hand, their absence is more than compensated for by the red hematite deposits of iron ore in the carboniferous limestone. As recently as the year 1854, the number of persons employed in Cumberland in iron mining did not exceed 369. In later returns, and until the "Metalliferous Mines Regulation Act, 1872," came into operation, those employed in coal and iron mines were not separately distinguished. Since the year

1873 reliable returns are available,* showing the numbers employed under and above ground, also the output of the mines, and the average produce of ore per man; the details are as follows:—

Year.	Persons Employed.		Total Employed.	Hematite Ore Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	3,438	1,004	4,442	917,452	206
1874	4,108	1,179	5,287	1,204,802	227
1875	4,217	1,345	5,562	1,130,201	205
1876	4,620	1,803	6,423	1,377,412	215
1877	4,826	1,551	6,377	1,478,338	232
1878	4,502	1,467	5,969	1,322,028	221
1879	4,088	1,393	5,481	1,223,338	223
1880	4,880	1,620	6,500	1,525,084	234

Pig Iron Manufacture.—The earliest facts bearing on this industry in Cumberland appears in Hutchinson's † history of that county, in which it is stated that "between Workington and Seaton, on the banks of the Derwent, are considerable iron-works, planned and built under the direction of that eminent engineer, the late Thomas Spalding, of Whitehaven, in the year 1763. They have two blast furnaces for the smelting of iron ore, a mill for slitting and rolling of bar iron, a double forge for refining and drawing of bar iron, a foundry, with several small furnaces, wherein they make cannon and cast-iron works of all sorts, a boring mill for boring cannon, cylinders, &c., a grinding house and turning house and many other conveniences for carrying on a very extensive iron manufactory. These works are carried on under the firm of Spedding, Hicks and Company." In the year 1796, two years after the publication of the volume from which the above is extracted, a return to Parliament, on the authority of Dr. M'Nab, shows that at that time there were two blast furnaces in operation, named Bearpot and Duddon, the latter, no doubt, being in the occupation of the ancestors of the present proprietors, Messrs. Harrison, Ainslie & Co.

The early history of the iron industries of Millom present some interesting features. The Huddlestons, of Millom Castle, had one or more charcoal blast furnaces near a stream still known

* Reports of H.M. Inspectors of Mines.

† "History and Antiquities of Cumberland." Hutchinson, Carlisle, 1794.

as Furnace Beck, and about a mile north-east from the castle, where, when the site had been ploughed, slag and pieces of iron were found. At Duddon Bridge a charcoal furnace is standing which is used from time to time as charcoal can be obtained, as are also those at Newland and Backbarrow, both in Furness. A fourth exists at Warsash in Hampshire, near Southampton, and a fifth at Lorn in Argyleshire. The Backbarrow furnace was in operation in the year 1745, also the Duddon, both furnaces being marked on Speed's Map of Cumberland, and they had probably been at work for years previously. These furnaces belonged to the family of Lathom, of Broughton in Furness, from whom they passed early in the present century to the old established firm of Harrison, Ainslie & Co., by whom they are still owned. Mr. Thomas Massicks, who has gleaned many important facts connected with the district, possesses, it is said, a pig of the iron made in Millom, and branded A.D. 1783, which was found doing duty as a lintel in a cottage at Hodbarrow. These are the only charcoal furnaces traced in the Millom district; and Mr. Massicks is of opinion that no part of the vast deposits of Hodbarrow were touched till about fifty years ago, when a small quantity was worked near the shore, and that the Huddlestone furnaces were partly supplied from a small vein in limestone close by, the remainder being brought from Furness.

The production of charcoal pig iron at the works of Bearpot and Duddon in 1796 was 2,080 tons and 1,664 tons, or a total of 3,744 tons. These charcoal furnaces, except the Bearpot, are still in existence, and in the year 1855 produced 16,574 tons of charcoal pig from hematite ore. The demand for this quality of iron at the period was considerable, it being extensively used in Birmingham for saddlers' ironmongery, where it was smelted in crucibles and run into small moulds; these castings were subsequently decarbonised by being placed in layers, with powdered hematite ore, in cylindrical pans, and exposed to a sufficient heat in suitable ovens, until all became malleable. The iron thus made has a wide reputation, and is only inferior to the best charcoal iron of Sweden, Russia and Norway. Blooms and bars were made at the Backbarrow works in Lancashire in 1855; the manufacture was, however, discontinued, through the failure of wood for making the charcoal.

In the year 1851 the production of pig iron in Cumberland was very limited, being confined to the Cleator Iron Company, near Whitehaven, who had three furnaces in operation, and the small charcoal furnaces already referred to. The make of pig iron in 1854 did not exceed 20,000 tons; about the year 1857 the works at Harrington of Mr. C. H. Plevins and those at Seaton of the Messrs. Smith and Co., were put in blast; in the following year the works of the Workington Iron Company commenced the make of hematite pig, with two furnaces. And in the year 1863 the West Cumberland Iron and Steel Company blew in three furnaces. Again, in the year 1870, the Maryport, Millom and Solway Companies commenced operations. At this period there were 33 furnaces built, of which 24 were in blast, making 255,178 tons of pig iron. Other works followed, at Moss Bay and Workington, in 1872, while the works of Parton commenced active operations in the year 1874. The Journal of the Iron and Steel Institute gives ample details in its pages, not only of the Cumberland ironworks, but of others throughout the kingdom; those of the west coast springing up in recent years so rapidly have a special interest, and the following account will show generally their extent and appliances. "In the works of the West Cumberland Hematite Iron and Steel Company, the largest and, in many respects, the most modern establishment in the Workington district, there are here six blast furnaces, each 55 feet in height, and varying from 18 to 21 feet in the diameter of the boshes, or widest part. The furnaces are blown by a pair of beam engines, having a blowing cylinder of 8 feet in diameter, and a steam cylinder of 3 feet 8 inches in diameter; the stroke of the piston being 8 feet 6 inches, and the engine working at the rate of 20 revolutions per minute. The oldest furnaces of the company were erected about the year 1860, in which year the blast engines were also erected. The blast furnaces are all fitted with the bell mouth and hopper apparatus, patented by Head, Wrightson & Co., for the utilization of the waste gases, which are conducted to the heaters and boilers in the usual way. The hoists used for the elevation to the top of the furnaces of the raw materials are also on a principle patented by Mr. Wrightson of the above-named firm, and well known both in the Cleveland district, where it has been extensively adopted, also in Wales, Staffordshire, and, more recently, in Scotland.

"Within a few miles of their furnaces the West Cumberland Company are working a coal royalty, which produces a quality of coal suitable for the manufacture of coke. This coal is brought to the blast furnaces in its raw state, and on either side of the yard separating the blast furnaces from the steel works of the company there are a large number of coke ovens at work. The coke is said to be of good quality, although it must come far short of the South Durham coke, seeing that the latter is always preferred for any special brand, and that there are other firms in the district that use no other. The production of the West Cumberland blast furnaces averages from 200 to 250 tons per week each. The general character of their arrangements is very much similar, apart from height and capacity, to those built in the Cleveland district. The company possess manifest advantages in the near proximity to the sea, which is within one hundred yards of the furnaces, and furnishes an illimitable tip for the slag, a boon which many ironmasters, occupying a more insular situation, and therefore, at a great loss in disposing of their waste vitreous produce, would highly appreciate.

"The steel works of the West Cumberland Company are separated by a distance of some three hundred yards from the blast furnaces, part of the intervening space being occupied with a small forge and workshop. With the exception of the works of the Barrow Company, these are undoubtedly the finest steel works on the west coast. Here there are found Bessemer convertors in operation, two having a capacity of 8 tons, and other two of 6 tons each. The operation of casting the ingots of steel is performed here in the ordinary way. In the subsequent processes, however, the rails are drawn out in lengths of 48 feet, and then in their red-hot state they are brought to a guillotine and cut into lengths of 21 feet each; so that for every two rails there are only two crop ends. In some cases it is found possible to draw out lengths of from 60 to 64 feet, thus allowing only two crop ends for three rails; but in general practice it is found better to keep to the shorter and more wieldy length of 48 feet.

"The Moss Bay Company's iron and steel works, situated near Workington, may be referred to as possessing all the modern improvements, and it was at these works that the appliances now nearly universally employed for utilizing the waste gases were first introduced into this district. A forge is attached to these

works, where a puddling furnace on a new principle is employed, patented by Mr. Kirk, the manager. These new furnaces work with a consumption of not more than 15½ cwt. of coal to the ton of puddled bar."

In the table below appears the number of furnaces built and in blast, with the make of pig iron in each year since 1857 :—

Year.	Furnaces.		Pig Iron Made.	Average per Furnace.
	Built.	In Blast.		
	Nos.	Nos.	Tons.	Tons.
1857	8	6	30,515	5,083
1858	8	5	26,264	5,253
1859	12	7	50,097	7,157
1860	12	8	87,950	10,993
1861	12	8	55,165	6,895
1862	12	7	103,455	14,779
1863	14	10	106,090	10,609
1864	15	11	141,033	12,821
1865	15	9	107,430	11,935
1866	17	12	136,343	11,362
1867	17	8¾	109,839	12,553
1868	17	8	116,864	14,608
1869	17	9	129,107	13,234
1870	27	24	255,178	10,632
1871	34	28¾	336,569	11,707
1872	37	33¼	440,575	13,250

The variation in the average yield of the furnaces, it should be stated, is due to the circumstance of some of the furnaces being in blast but a part of the year. In considering the quantity of coal used in the manufacture of pig iron, the average amount used about the year 1869 was 60 cwt., subsequently it was determined by inquiries specially made, that in the year 1873 the average did not exceed 51 cwt. in Great Britain; while in this district, where the Durham coke is extensively employed, the average did not exceed 47 cwt., all purposes included; and in all cases where coke was returned its equivalent in coal has been taken.

Coal and Iron Ore used in Manufacture.—In the year 1872 inquiries were first instituted with a view of ascertaining the quantities of fuel and ore used in the manufacture of pig iron. The results appear in the annexed table giving the number of furnaces built and in blast in Cumberland, the make of pig iron, and the coal and iron ore employed :—

Year.	Furnaces. Built.	Furnaces. In Blast.	Pig Iron Made.	Coal Used.	Ore Used.
	Nos.	Nos.	Tons.	Tons.	Tons.
1872	37	33¼	440,575	1,077,783	850,500
1873	39	33½	456,877	1,079,118	865,172
1874	51	30½	390,840	1,010,125	738,490
1875	51	31¾	486,112	1,089,000	846,000
1876	47	25	436,887	936,929	783,456
1877	50	26¾	538,156	1,027,869	956,834
1878	51	27	542,904	1,019,957	976,059
1879	51	27½	531,638	1,005,497	930,247
1880	51	40	790,343	1,604,097	1,475,280

In the year 1872 the coal used in pig iron manufacture, all purposes included, was 49 cwts. to each ton of pig iron made, compared with 47½ cwts. in the following year; successive years show improved economy. Taking the years 1879 and 1880 the average varies between 38 and 40 cwts.

The works and furnaces in operation in Cumberland during the year 1880 were as follows; producing, as stated, 790,343 tons of pig iron suitable for the manufacture of steel:—

CUMBERLAND.

No.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In Blast.
			Nos.	Nos.
1	Derwent	Derwent Hæmatite Iron Co., Lim.	3	3*
2	Duddon	Harrison, Ainslie, & Co. . .	1	0
3	Harrington Hæmatite, Whitehaven . .	James Bain & Co.	4	3
4	Lonsdale, Whitehaven . .	Lonsdale Hæmatite Iron & Steel Co.	4	4†
5	Lowther, Workington . .	Lowther Hæmatite Iron Co., Lim.	3	2
6	Maryport	Maryport Hæmatite Iron Co. . .	6	6
7	Millom	Cumberland Iron Mining & Smelting Co., Limited .	6	5
8	Moss Bay, Workington . .	Moss Bay Hæmatite Iron & Steel Co.	4	3
9	Parton, Whitehaven . .	Parton Hæmatite Iron Co., Lim.	2	1‡
10	Solway Hæmatite, Maryport .	Solway Hæmatite Iron Co., Lim.	4	2§
11	West Cumberland Iron and Steel, Workington . . .	West Cumberland Iron & Steel Co., Limited . . .	6	5*
12	Whitehaven Hæmatite, Cleator Moor	Whitehaven Hæmatite Iron Co., Limited	4	3‖
13	Workington	Workington Iron Co., Limited .	4	3
		Total of Cumberland . .	51	40

* One furnace for six months. † One furnace for seven and a half months.
‡ Another furnace for six weeks. § A third furnace for three months.
‖ One furnace a part of the year only.

As to the ore employed, all varieties included give an average in 1872 and 1873 of about 38 cwts., compared with 36 cwts. in recent years. The great bulk of the ore reduced in the Cumberland furnaces is the produce of the district, the other ores imported and used in admixture were derived from the following sources in each year since 1875:—

	1875.	1876.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Hæmatite .	809,703	740,710	906,991	914,475	890,456	1,360,410
Foreign . .	15,178	23,500	28,776	29,000	16,308	79,424
Irish . .	21,119	14,029	17,487	18,633	15,791	28,206
Other ores . .	..	5,217	3,580	13,951	7,692	17,240
Totals .	846,000	783,456	956,834	976,059	930,247	1,475,280

The Irish aluminous ore is used with considerable advantage as a flux in the smelting of the hæmatite, as it contains from 20 to 35 per cent. of alumina, and from 35 to 40 per cent. of metallic iron; there was also employed a small amount of forge and mill cinder, containing from 40 to 70 per cent. of metallic iron.

Malleable Iron and Steel Works.—In the year 1872 there were five works engaged in the manufacture of malleable iron, employing 83 puddling furnaces and 11 rolling mills, to which should be added the Bessemer Works of the West Cumberland and the Moss Bay Iron and Steel Companies, situated near Workington. The coal used in the above works in the years 1872 and 1873 amounted to from 100,000 to 110,000 tons, whereas the total quantity of coal employed in the malleable iron works of Cumberland in 1880 and two preceding years has not exceeded 35,000 tons per annum. The following is a list of the works, with the number of puddling furnaces and rolling mills in operation in the year 1880:—

Name of Works.	Name of Firm.	Puddling Furnaces.	Rolling Mills.
		Nos.	Nos.
West Cumberland .	West Cumberland Iron & Steel Co., Limited . .	0	3
Derwent Rolling Mills	Moss Bay H. Iron & Steel Co.	13	2
New Yard . . .	Kirk Brothers & Co. . .	7	1
Marsh Side . .	,, ,, . .	8	1
Ellen Rolling Mills .	Penton, Hampton, & Jackson	*13	2
	Total . . .	41	9

* Works standing.

The four first named works are situated near Workington, and the last near Maryport, which has been standing for some years.

The production of Bessemer steel in the Cumberland works in the year 1879 amounted to 127,163 tons of ingots, increased in 1880 to 140,869 tons of ingots, showing an increase of 13,706 tons of ingots over the previous year. The production of Bessemer steel rails in 1879 amounted to 103,969 tons, and in 1880 to 114,096 tons, showing an increase of 10,127 tons in the last-named year. The total output of Bessemer steel rails in Great Britain in the years 1879 and 1880, according to the annual reports of the British Iron Trade Association for those years, being respectively 519,718 tons, and 739,910 tons, giving an increased production in 1880 of 41 per cent. over the previous year.

CHAPTER V.

LANCASHIRE IRON INDUSTRIES.

Description of Iron Ore deposits in Furness—Analyses, production and distribution of Ore—Iron Mines in Lancashire—Population employed in Iron Mining—Pig Iron Manufacture—Early history—Barrow and Wigan Coal and Iron Co.'s Works—Production of Pig Iron—List of Iron Works—Malleable Iron and Bessemer Steel Works, and Coal employed—Mersey Steel Works—Coal and Iron Ore used in Pig Iron Manufacture—Sources of Iron Ore.

Lancashire. Iron Ore Deposits. Carboniferous Limestone.—So closely do the iron ores of North Lancashire resemble those of Cumberland, both in their mineralogical character and in their mode of occurrence, that little need be added to what already has been said on the deposits of similar character in the adjoining county of Cumberland. Whilst the Cumberland hæmatite is for the most part a hard ore, the predominating mineral in the Furness district is a soft hæmatite, often containing, however, embedded pieces of a compact variety; most of this soft ore is used for fettling puddling furnaces. It is notable that many of the irregular deposits of ore in the carboniferous or "Mountain Limestone" of Furness extend upward to the level of the limestone, and are overlain merely by deposits of drift; from such a mode of occurrence it may be naturally inferred that the denudation which the ore-bearing rocks have suffered has removed the upper portions of the deposits, and that the drift was accumulated upon the exposed surface of ore. Some of these mineral deposits in Furness are of considerable extent; for example, the ore worked at Park, and at the Roanhead Mines, forms a deposit extending for upwards of 500 yards in length, its width varying from 120 to 240 yards.

As in the Whitehaven district, so in Furness, the ore is not confined to irregular deposits in the limestone, but is found also in more or less regular fissures, which generally have a north-west and south-east strike, with a dip to the south-west. Thus the mines at Stank, which are the deepest in the Furness district,

are worked upon one of these fissures of hæmatite, dipping 45° to the south-west; this is known to extend for a length of more than 500 yards, and is in part as much as 30 yards in width. Mr. P. Wurzburger gives further interesting details of the deposits in this district in his paper read before the Barrow-in-Furness meeting of the Iron and Steel Institute, in August, 1874.

Analyses of the Ore.*—The hæmatite of the Lindal Moor Mines, near Ulverstone, of Messrs. Harrison, Ainslie, and Company, and worked extensively, has been examined by Mr. John Spiller, who described it as follows:—"The sample was selected from a large quantity of ore, consisting of fragments of various degrees of hardness, the majority of which were of the hard compact variety, deep grayish purple in colour, and covered with a brownish red unctuous powder; there were also small quantities of fibrous hæmatite and specular iron, together with quartz and a little earthy matter."

RESULTS TABULATED.

Peroxide of iron	94·23
Protoxide of manganese	0·23
Alumina	0·51
Lime	0·05
Magnesia	trace.
Phosphoric acid	minute trace.
Sulphuric acid	0·09
Bisulphide of iron	0·03
Water, hygroscopic	0·39
Water, combined	0·17
Insoluble residue	5·18
Total	100·88

INSOLUBLE RESIDUE.

Silica	4·90
Alumina	0·12
Peroxide of iron and lime	traces.
Total	5·02

The total amount of metallic iron contained in the ore being equivalent to 65·98 per cent., a distinct trace of arsenic being detected in 1680 grains of the ore.

The hæmatite raised at Gilbrow,* also near Ulverstone, examined by Mr. A. Dick, is thus referred to:—"Description.—Red hæmatite; unctuous; easily scratched by the file; lustre,

* "Iron Ores of Great Britain," Part I., p. 66.

sub-metallic; colour, purplish red; streak, bright red; fracture, uneven and minutely crystalline; pieces of carbonate of lime and other minerals occur in it, which getting coloured by the powder, cannot be seen until the specimen is washed. Total amount of metallic iron contained in the ore is equivalent to 60·55 per cent."

RESULTS TABULATED.—ORE DRIED ABOVE 100° C.

Peroxide of iron	86·50
Protoxide of manganese	0·21
Lime	2·77
Magnesia	1·46
Carbonic acid	2·96
Phosphoric acid	trace.
Sulphuric acid	0·11
Insoluble residue	6·55
Total	100·56

INSOLUBLE RESIDUE.

Silica	6·18
Alumina containing a trace of iron	0·30
Total	6·48

A whitish metal, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, was found. The quantity obtained from 500 grains of ore was so small that it could not be identified.

The poorer ores in the Furness district average 45 per cent. of metallic iron, while 50 per cent. of iron are found in similar ores in the Whitehaven district. The following series of analyses, by Richards, shows the constituents of some of the best hæmatite ores of Barrow-in-Furness, employed in making Bessemer pig-iron in the Barrow Works:—

Constituents.	Park.	Whitriggs.	Mouzell.
Peroxide of iron	94·88	83·33	83·94
Alumina	0·07	0·75	0·70
Protoxide of manganese	0·04	0·08	0·28
Lime	0·34	4·10	0·85
Magnesia	trace.	0·15	0·09
Water	0·47	1·97	2·28
Phosphoric acid	0·03	...	0·03
Sulphuric acid	...	trace.	...
Carbonic acid	...	2·53	...
Silica	4·55	6·59	12·46
Total	100·38	99·50	100·63

The Park ore gives 66·42 per cent. of metallic iron, the Whit-riggs and Mouzell yielding respectively 58·38 and 58·76 per cent. The ore used at Askam has the following composition:—

Peroxide of iron	83·00
Silica	15·50
Carbonate of lime	trace.
Moisture	1·50
Total	100·00

And yielding of metallic iron 58·10 per cent. It may be remarked, regarding these ores, that the harder variety is invariably used in the manufacture of hæmatite pig-iron, and is therefore called blast ore. The average yield of the Lancashire hæmatite may be taken as 64 per cent.

The following are analyses of other ores smelted at the Barrow Hæmatite Iron and Steel Company's works, and obtained from the localities named:—

Constituents.	Lindal Moor (Blast Ore).	Lindal Cote (Puddling Ore).	Lindal Moor (Puddling Ore).	Dalton (Blast Ore).	Newton (Blast Ore).
Sesquioxide of iron	78·61	77·24	86·20	67·14	77·64
Phosphoric acid	0·03	...	...	...	...
Phosphorus	0·01	...	...	...	trace.
Sulphuric acid	0·04	...	0·04	...	trace.
Carbonic acid	...	4·19	1·43	4·45	trace.
Silica	0·04	0·09	0·08	...	0·01
Alumina	trace.	0·24	0·43	0·25	0·15
Protoxide of manganese	0·24	0·11	trace.	0·08	0·13
Lime	0·57	6·00	2·23	6·02	1·09
Magnesia	0·19	0·41	0·59	0·15	0·14
Water	2·02	2·82	3·35	1·80	3·08
Insoluble residue	18·31	9·07	6·50	19·77	17·94
Total	100·06	100·17	100·85	99·66	100·18
Insoluble Residue.					
Silica	16·11	7·27	5·58	19·09	15·44
Alumina	1·67	1·47	0·58	0·51	2·13
Lime	0·03	0·08	0·05	0·12	0·06
Magnesia	0·05	trace.	trace.	trace.	trace.
Total	17·86	8·82	6·21	19·72	17·63
Metallic Iron	55·03	54·07	60·34	47·00	54·35

Production of Hæmatite.—Taking a retrospective view of the iron trade in Barrow and the Furness district in the beginning of this century, it appears, according to the books of the Harbour Trustees, that the total quantity of ore sent from the port of Barrow, in the year 1800, was but 1,200 tons, compared with 146,000 tons in the year 1849, when Mr. Braithwaite Poole made a report on iron ore to the Directors of the Lancaster and Carlisle Railway Company. At this period, according to the above report, there appears to have been, in Great Britain, 60 mines in operation, the output of ore amounting to 500,000 tons per annum, and employing miners, bankmen, carters, and others, to the number of nearly 3,000 men, while the value of the ore thus raised annually was estimated to reach £500,000. The mines and firms raising hæmatite, in Lancashire, in 1849, were as follows, producing in the Furness district 182,000 tons, of an average of 64 per cent. of metallic iron:—

No.	Mines.	Proprietors.	Tons.
3	Lindal Moor . .	Harrison, Ainslie, and Co. .	55,000
3	Cross Gates . .	Town and Rawlinson . . .	42,000
4	Lindal Cote . .	Ulverstone Mining Co. . .	29,000
3	Mouzell . . .	Schneider, Davis, and Co. . .	25,000
1	Haulme . . .	Charles Kennedy . . .	12,000
2	Stainton . . .	George Huddleston . . .	12,000
1	Elliscales . . .	George Ashburner . . .	7,000
17		Total . .	182,000

Of this quantity 146,000 tons were shipped at Barrow, 33,000 tons disposed of by the Ulverstone Canal, the remaining 3,000 tons being consumed in the district in the works of Messrs. Harrison, Ainslie, and Co. The distribution of the ore was as follows:—

DISTRIBUTION.	TONS.
South Wales	87,000
Staffordshire	84,000
Furness district	3,000
Yorkshire	3,000
North Wales and Salop	2,000
Scotland	2,000
Newcastle and Durham	1,000
Total of Furness Ore	182,000

The average selling price at Barrow at this period was 10*s*. 6*d*. per ton; the cost of getting and other incidental charges being shown in the annexed items:—

	s.	*d.*
Royalty	1	6
Working	2	6
Propwood	1	0
Interest of value of stock	1	0
Carriage (cartage)	1	4
Railway to Barrow	1	9
Profit, including mining risks, bad debts, &c.	1	5
Selling price at Barrow, per ton	10	6

The cost of carriage from Barrow to South Staffordshire by canal and railway appears in the following items, long weight of 2,400 lbs. to the ton:—

BY SEA AND CANAL.	*s.*	*d.*
Freight from Barrow to Ellesmere Port	2	6
Charges wharfage and porterage at ditto	1	3
Town dues	0	3
Canal charges (say to Spring Vale) *	7	0
Loss of ore by laying in open wharves at 2½ per cent.	0	3
Total long weight	11	3

BY RAILWAY.	*s.*	*d.*
Freight from Barrow to Fleetwood or Poulton	1	6
Charges, wharfage and porterage at ditto	0	9
Railway charges (say to Golds Hill) †	8	0
Short weight *v.* long weight = 1-14th	0	9
Total long weight	11	0

Five years later, in 1854, the united production of the Lancashire and Cumberland mines amounted to 579,924 tons. Most of the mines producing this ore have since acquired a high reputation, on account of the vast deposits discovered, and the superior character of the metal produced therefrom, more especially since the introduction of the Bessemer process. The ore raised in 1854 was distributed thus:—to the Newcastle district, 6,785 tons; North Wales, 13,380 tons; South Staffordshire, principally by the London and North-Western Railway, 300,000 tons; and

* Mr. George Jones' Iron Works, near Wolverhampton.

† Messrs. Bagnall & Sons' Iron Works, near Tipton. These two works being at an average distance.

by ship coastwise to South Wales, 150,000 tons; showing how great was the demand at this time for these ores, to augment the supplies to other iron-making districts, the high per centage of metallic iron they contained enabling them to bear a considerable cost for transport to remote districts.

In subsequent years the production of the Lancashire mines is separately distinguished from those of Cumberland, amounting in the year 1855 to 336,829 tons, the total output of the mines of Great Britain the same year being 9,553,741 tons. The only ironworks existing in Lancashire at this period being those of Messrs. Harrison, Ainslie and Co., at Newland and Backbarrow, previously referred to, where the ores obtained from their Lindal Moor mines were smelted and pig-iron made with charcoal.

In the annexed table is shown the output of Lancashire hæmatite, in each year since 1855:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1855	336,829	1868	767,625
1856	464,853	1869	784,507
1857	592,390	1870	871,938
1858	438,456	1871	931,048
1859	445,046	1872	909,077
1860	520,829	1873	975,826
1861	519,180	1874	914,357
1862	559,391	1875	834,484
1863	658,642	1876	908,664
1864	691,421	1877	993,012
1865	607,439	1878	984,781
1866	685,726	1879	976,822
1867	667,356	1880	1,266,503

In considering the value of these ores it may be stated that in the year 1871 and the two following years prices ranged from 19*s*. 9*d*. per ton in 1871, to 28*s*. 6*d*. per ton in 1872; and even this was eclipsed in the year 1873, when prices rose to 32*s*. per ton. In subsequent years prices have gradually diminished, thus, in the year 1878, the following are a few of the more important quotations of Lancashire ore delivered in trucks at the pits; Lindal Moor, 15*s*.; Askham, 14*s*. 6*d*.; Roundhead, 13*s*. to 14*s*.; the lowest price quoted being 10*s*. 9*d*. per ton.

The average price of ore in 1878, through and through, was 12*s*. 6*d*. per ton compared with 13*s*. 6*d*. in 1880. In the an-

nexed table appears the output of each iron mine in Lancashire in the year 1880, with the value of the ore :—

Name of Mine.	Quantities. Tons.	Cwts.	Value. £	s.	d.
Askham (Furness Iron and Steel Co.)	2,303	0	1,381	16	0
Dalton ,, ,, ,, .	45,468	0	27,280	8	0
Dalton (Myles Kennedy) . . .	7,236	0	4,532	10	0
Elliscales	22,908	15	13,744	16	0
Highfield	6,462	0	4,696	10	0
Lindal Cote, Eure pits, &c. . .	29,998	0	20,247	13	0
Lindal Moor (Furness Iron and Steel Co.)	16,031	0	10,820	12	0
Lindal Moor, Whitriggs and Gilbrow	257,696	0	173,944	16	0
Lindal and Ousby	1,831	0	1,098	12	0
Lindal-in-Furness (Wigan Coal and Iron Co.)	644	0	386	8	0
Mouzell	92,597	0	53,264	5	0
Newton (Barrow H. S. Co.) . .	1,858	0	1,300	0	0
Old Hills ,, ,, . . .	3,575	0	2,502	10	0
Park ,, ,, . . .	305,415	0	213,790	0	0
Stank ,, ,, . . .	127,910	0	89,538	10	0
Pennington (Parkside Mining Co.).	29,326	0	20,528	0	0
Roanhead and Askham . . .	218,363	0	152,854	0	0
Stainton (Stainton Mining Co.) .	4,304	19	3,013	10	0
Whitriggs (Barrow H. S. Co.) . .	43,335	0	30,334	10	0
Yarlside (Parkhouse) . . .	49,242	0	35,700	0	0
Total of Lancashire . .	1,266,503	14	860,959	6	0

Since the year 1872 the mines of the Barrow Hæmatite Steel Company have produced ore in the following quantities :—

Year.	Newton. Tons.	Old Hills. Tons.	Park. Tons.	Stank. Tons.	Whitriggs. Tons.	Stainton. Tons.
1872	6,300	*	262,305	6,052	10,965	1,770
1873	4,339	*	283,496	13,246	16,185	2,347
1874	5,234	2,296	270,469	22,285	14,252	2,721
1875	6,254	*	245,045	50,891	19,981	2,043
1876	5,626	4,338	232,374	67,420	27,471	111,875
1877	6,200	3,441	219,462	77,151	29,902	229
1878	5,269	6,417	208,329	110,917	29,961	1,400
1879	1,656	2,632	226,107	114,936	30,445	727
1880	1,858	3,575	305,415	127,910	43,335	...

In the annexed table the Roanhead Mines, the property of Messrs. Denney and Co., the Lindal Moor of Messrs. Harrison,

* Included in Whitriggs.

Ainslie and Co., and the Askham, Lindal Moor and Dalton Mines of the Furness Iron and Steel Company, produced ore in the following quantities since the year 1872 :—

Year.	Askham.	Lindal Moor.	Dalton.	Roanhead, &c.	Lindal Moor.
	Tons.	Tons.	Tons.	Tons.	Tons.
1872	5,718	4,407	...	170,769	158,341
1873	25,881	45,005	...	199,017	153,138
1874	23,679	32,749	29,154	187,455	160,474
1875	16,571	8,138	8,616	131,210	167,049
1876	11,215	13,276	5,334	129,508	193,040
1877	10,050	10,787	13,996	134,670	219,812
1878	10,154	12,346	28,406	134,464	224,389
1879	8,795	15,368	47,315	138,452	225,827
1880	2,303	16,031	45,468	113,551	257,696

The average prices in 1879 from these mines varied from 10*s.* to 15*s.* 6*d.* per ton, and in 1880 about 13*s.* 6*d.* per ton.

Distribution of the Ore.—Except some inconsiderable quantities of ore carried in a few localities to the ironworks by road, the great bulk of the ore is distributed by the Furness Railway, either to Barrow for shipment to other ports, or by rail to Yorkshire, Staffordshire, &c., and to the ironworks of the county.

The earliest return published for the year 1855 gives the annexed account of the distribution of ore in that year:—

DISTRIBUTION OF THE ORE.	QUANTITIES.
	Tons.
Shipped at Barrow	313,797
,, to Scotland	1,470
,, for Yorkshire, &c.	1,500
By rail to Yorkshire, Staffordshire, and Wales . . .	17,711
Consumed in district	2,351
Total production in 1855	336,829

Lancashire, with her valuable resources of rich red hæmatite, was not destined to remain a repository only for the supply of other districts; as time rolled on a remarkable development took place, and in due course some of the best arranged smelting works were established, and a great industry was created, absorbing in 1880 nearly three-fourths of all the ore raised. This will appear in the annexed table, showing the respective quantities sent by ship, rail, and to the iron furnaces of the district in each of the years since 1856, by the Furness Railway:—

Year.	By Ship.	By Rail.	To Furnaces.	Total.
	Tons.	Tons.	Tons.	Tons.
1856	461,303	...	3,550	464,853
1857	574,952	14,729	2,709	592,390
1858	367,568	69,028	1,950	438,456
1859	305,136	130,896	9,014	445,046
1860	259,477	181,712	79,640	520,829
1863	238,882	205,701	204,059	658,642
1866	163,725	188,701	333,300	685,726
1869	96,322	177,630	510,555	784,507
1871	74,732	253,478	602,838	931,048
1873	73,164	239,669	662,993	975,826
1875	63,926	118,459	628,230	810,615
1876	65,423	105,677	662,566	833,666
1877	42,657	97,767	762,412	902,836
1878	25,356	120,737	733,387	879,480
1879	30,981	95,200	787,745	913,926
1880	50,557	139,328	939,858	1,129,743

The following account gives the details of the distribution of the ore by rail and ship in the year 1880:—

	TONS.	TONS.
Shipped at Barrow to South Wales	12,102	
,, Lancashire, North Wales, &c..	20,552	
,, Scotland	16,542	
,, Foreign Parts	1,361	
		50,557
Shipped at Ulverstone Canal		...
By rail to Lancashire, Yorkshire and Staffordshire .	139,328	
,, furnaces in district	939,858	
		1,079,186
Total *by sea and rail*		1,129,743

Beyond the above quantities, 136,760 tons of ore were conveyed to the ironworks by road, compared with 62,896 tons in 1879.

Examining the quantities appearing under the respective heads in the above table, some interesting facts appear, deserving of attention. Already the increased consumption of the blast furnaces has been referred to: a glance at the quantities carried to the shipping ports and sent coastwise to distant iron districts, shows a remarkable decline from 574,952 tons in the year 1857 to 25,356 tons in the year 1878. The quantities sent out of the district by rail on the other hand has not varied to any great extent since the year 1859, except between the years 1871 and 1873, which will ever be remembered in the history of the coal

and iron industries as a time of great prosperity; thus, in 1859 the ore sent out of the district reached 130,896 tons, compared with 253,478 tons in the year 1871, and 233,238 tons in the year 1872, since which the quantities sent away show little variation.

The diminished export of ore from the Furness deposits to other districts, where it was in great request, has been to some extent accounted for by the additional imports from foreign countries, particularly from Spain, amounting in the year 1880 to 2,278,962 tons, of the value of £2,270,462, giving an average of 20*s.* per ton; the total imports of iron ore the same year being 2,632,601 tons of the value of £2,789,929.

Examining the distribution of the Furness ore, the following figures for a few years will show the falling off to those districts formerly receiving it in considerable quantities by both sea and rail:—

Destination.	1868.	1873.	1878.	1880.
By Sea.	Tons.	Tons.	Tons.	Tons.
South Wales . . .	78,338	50,777	11,750	12,102
Lancashire and North Wales . . .	47,339	18,194	7,098	20,552
Scotland . . .	4,365	4,138	5,731	16,542
Foreign Parts . . .	130	55	777	1,361
By Rail.				
Lancashire, Yorkshire, &c.	82,978	198,911	120,737	139,328
Scotland	350	2,937	...	...
Newcastle, Stockton, &c.	48,057	37,821	...	...
Total . .	261,557	312,823	146,093	189,885

Recent explorations of the iron ore deposits of Furness have disclosed some interesting facts, showing that they are far more important and extensive than was formerly considered. The Mouzell Mine, near Dalton-in-Furness, was surrendered to the owner in December, 1877, by the Barrow Hæmatite Iron and Steel Company. Subsequent explorations, conducted by the manager for the owner, have resulted in the discovery of an extensive basin at least 70 yards in length, and varying in width from 30 to 40 yards, and in depth from 20 to 30 yards.

The mines, situation, proprietors or companies and chief agents, now in operation in Lancashire, are as follows:—

No.	Name of Mine.	Situation.	Name of Proprietor or Company.	Name of Manager or Agent.
1	Askam	Askam-in-Furness .	*Furness Iron and Steel Co., Limited .	Henry Mellon.
2	Crossgates . .	Near Dalton . .	" .	"
3	Dalton	" . .	" . .	"
4	Lindal Moor . .	Ulverston . . .	" .	"
5	Martin		" .	"
6	Goldmire	"	" .	"
7	Pennington . . .	"	" . .	"
8	Plumpton . . .	"	" .	"
9	Thwaite Flatt . .	Dalton	" . .	"
10	Stainton . . .	"	Barrow Hæmatite Steel Co., Limited .	William Kellett.
11	Newton . . .	"	" . .	"
12	Park	"	" .	"
13	Old Hills . . .	"	" . .	"
14	Whitriggs . . .	"	" .	"
15	Pennington . . .	Lindal	Parkside Mining Co. .	George Scoular.
16	Urswick	"	" .	"
17	Stank	Dalton	Barrow Hæmatite Steel Co., Limited .	William Kellett.
18	Stainton . . .	"	The Stainton Mining Co.	James Garstang Brogden.
19	Bercume . . .	Ulverston . . .	Rigg & Co. . . .	Captain Goldy.
20	Mouzell	Dalton	John Clegg . . .	James Ashworth.
21	Dalton	"	Myles Kennedy . .	Miles Kennedy.
22	Elliscales . . .	"	Elliscales Mining Co. .	Joseph Askew.
23	Lindal Cote, Eure Pits and Crossgates	" , offices Ulverston	The Ulverston Mining Co., Limited . .	J. G. Brogden.
24	Lindal Moor . .	" .	Harrison, Ainslie, & Co.	Edmund Ray.
25	Gilbrow and Whitriggs . . .	" . .	" . .	"
26	Highfield . . .	Dalton	Cumberland Iron Mining and Smelting Co., Limited .	Thomas Massicks.
27	Longlands . .	"	Duke of Buccleuch . .	Edward Wadham.
28	Roanhead and Askam	"	Kennedy Brothers .	Myles Kennedy.
29	Urswick . . .	Ulverston . . .	Begbie & Co. . . .	H. D. V. Begbie.
30	Lindal and Ousby .	Little Urswick . .	Lindal and Ousby Iron Ore Co., Lim. .	Hy. Postlethwaite.
31	Yarlside . . .	Dalton	Thos. Storey and Wm. Boulton . . .	Wm. Boulton.

Population employed in Ironstone Mining.—The earliest return published for the year 1873 shows that of 3,222 persons employed in Lancashire in the Hæmatite Iron Mines 1,890 were employed underground, and 1,332 above ground, producing 852,064 tons of iron ore. These returns refer only to those mines under the operation of the "Metalliferous Mines Regulation Act, 1872;" the total iron ore produced in Lancashire in the same year was 928,174 tons, the difference, 76,110 tons, being the output of mines not coming under the operation of the above-named Act.

The annexed table, constructed from the Annual Reports of H.M. Inspectors of Mines, gives the total numbers of persons employed under ground and above ground in each of the years, with the total output and average produce per man:—

* In liquidation.

Year.	PERSONS EMPLOYED.		Total Employed.	Iron Ore Raised.	Average per Man.
	Under Ground.	Above Ground.			
				Tons.	Tons.
1873	1,890	1,332	3,222	852,064	264
1874	2,135	1,462	3,597	934,234	260
1875	1,812	1,275	3,087	882,840	286
1876	1,950	1,247	3,197	858,894	268
1877	2,061	1,162	3,223	913,060	283
1878	2,194	1,121	3,315	906,994	273
1879	2,008	1,140	3,148	979,659	311
1880	2,807	1,426	4,233	1,188,543	280

The steady working of the ironstone miner is apparent in these returns, showing an increase in the eight years of 16 tons per man, equivalent to 7 per cent.

Pig Iron Manufacture.—As far back as the year 1788 evidence appears of the existence of small furnaces in Lancashire, where iron ore was smelted with the aid of charcoal; these were situated and known as the Newland, Backbarrow, and Leighton furnaces, and their production is recorded in the year named as 2,100 tons, or 700 tons per furnace. Another return for the year 1796 records the make of the two first named as 700 tons, and the Leighton furnace as 780 tons, or an aggregate for that year of 2,180 tons, being an increase of 80 tons in six years.

The total make of pig iron in 1788 was of charcoal pig iron 13,100 tons, and of coke pig iron 48,200 tons, giving an aggregate of 61,300 tons to England and Wales; and a further sum of 7,000 tons to Scotland, of which 1,400 tons were charcoal pig and 5,600 tons coke pig iron, making in all 68,300 tons. Again, in 1796, according to the return prepared by Dr. Macnab and presented to a committee of the House of Commons, the details of which return will be found in another page, the total make of the furnaces of Great Britain amounted to 125,079 tons, of which 3,780 tons were charcoal pig and 121,299 tons coke pig iron.

In 1806 the Leighton furnace was alone in operation; as far as can be ascertained the make of pig iron for that year was 780 tons, as in the year 1796. Some years later Mr. David Mushet ascertained that the quantity of charcoal iron made in Lancashire did not exceed 800 tons; this was about the year 1839, the works producing this quantity being those at Newland and at

Backbarrow, as previously stated, of Messrs. Harrison, Ainslie, and Co., the firm having others at Duddon in Cumberland, at Lorn near Bunawe in Argyleshire and at Warsash in Hampshire; these furnaces still exist, though only in operation at intervals, and are the only remaining charcoal furnaces in Great Britain. The firm above-named was, until the year 1858, the only one in Lancashire making pig iron; it was in that year that the Wigan Coal and Iron Company, at their works at Kirkless Hall, Ince, near Wigan, put two furnaces in blast, the make of pig iron in Lancashire at this period was 2,840 tons, which includes the charcoal iron made at the furnaces of Messrs. Harrison, Ainslie, and Co. The Messrs. Schneider and Hannay, in the year 1859, at their works at Barrow put three furnaces in blast, increasing the number in the county to seven, the aggregate make of which in the same year amounted to 26,491 tons. Advancing to the year 1860 the Wigan Company put another furnace in blast, making 10 built in the county, of which eight were in operation, producing 81,250 tons of coke and charcoal pig iron. About this time other works already projected commenced; the Carnforth Hematite Iron Company in the year 1866 blew in two furnaces; the Ditton Brook Company three in the year 1868; and the Furness Iron and Steel Company the same number in the year 1871.

The Darwen Iron Company commenced operations in the year 1874 with two furnaces; and the Outwood Iron Company at Outwood, near Ratcliffe, with one furnace the same year; while in the year 1875 the North Lonsdale Hematite Iron Company added two furnaces to the district, bringing the total number of those erected up to 50, of which 31 were in blast.

Returning to the production of charcoal pig iron in Lancashire, an occasional return is met with showing the quantities made. In the year 1857 the works at Newland and Backbarrow produced 1,233 tons; in 1859 the same works produced 720 tons. The make of these furnaces since that date is included in the yield of the Lancashire furnaces, but it is estimated that the make of charcoal pig iron in Lancashire is not less than 1,400 or 1,500 tons per annum.

Since the year 1860 the number of furnaces built, and in blast, the pig iron made, and the average yield of the furnaces have been as follows:—

Year.	Furnaces.		Pig Iron made.	Average per Furnace.
	Built.	In Blast.		
	No.	No.	Tons.	Tons.
1860	10	8	81,250	10,156
1861	12	10	109,377	10,937
1862	14	11	138,563	12,597
1863	17	11½	164,110	14,270
1864	17	13½	195,460	14,478
1865	24	16½	204,925	12,420
1866	25	19	268,680	14,141
1867	25	19	318,801	16,780
1868	28	22½	325,367	14,460
1869	30	27	436,662	16,173
1870	33	27	422,728	15,656
1871	41	34	520,359	15,300

A brief description of the Barrow Hematite Works and of the Kirkless Hall Works will indicate the magnitude and extent of these important metallurgical establishments.* "At the works of the Barrow Hematite Steel Company there are altogether 16 blast furnaces, 14 of which are built in a single row, while the remaining two are distant about half a mile. The weekly production of the blast furnaces averages 5,500 to 6,000 tons; but it is always calculated that two or three furnaces are out for alteration or repairs." The average height of the furnaces is about 63 feet, some of them being 62 feet and others 65 feet high. The first furnaces, built in 1859, were only 45 feet high; but these furnaces have recently been raised to 62 feet. The average consumption of fuel is one ton of coke per ton of pig iron made. The ore, which is obtained at the Company's own Mines, near Ulverston, averages 60 per cent. of metal. The consumption of limestone is about 9 cwts. per ton of iron made. The blast is heated to a temperature of 900° to 1,100°, according to the quality of the iron required. Each furnace is fitted with six tuyeres, the diameter of the nozzles being 3½ inches to 4 inches. The larger furnaces have a bosh of 20 feet diameter, and the smaller ones a bosh of 19 feet. The blast is partly heated by Cowper's and partly by Gjers's stoves. The engines that blow the blast are a remarkable feature of the ironworks. There are three beam and 18 grasshopper engines. Of the latter kind, not less than 10 are in one engine-house, which is said to be the largest engine-house in the world. With the exception of the

* "Journal of the Iron and Steel Institute," 1874, p. v. appendix.

buildings that contain the beam engines all the engine-houses are built parallel with the blast furnaces on the contrary side from the pig iron beds. The beam engines have double-acting high-pressure steam cylinders, 48 inches diameter and 9 feet stroke, the blowing cylinder being 72 inches diameter. The hoists are inclined planes, and are worked by special engines, there being a separate engine for each of the six inclines that are attached to the 14 furnaces. The hoist engines are of the ordinary reversing kind, worked by frictional gearing. The drum is 12 feet diameter, and the cylinders of the engines are 16 inches, with two feet length of stroke. Most of the engines have been made by Perry and Sons, of Bilston. All the furnaces are fitted up with the apparatus for the utilization of the waste gases, which are sufficient to supply all the heaters and boilers without any other fuel. The blast furnaces are distant about 200 yards from the steel works, the intervening space being occupied by sidings and filling sheds, and a spacious cast-iron bridge, spanning the whole of these sidings, connects the one department with the other. The steel works are in three large bays or roofs, each 700 feet in length. The pig iron on being brought from the blast furnaces is stored here in rather a peculiar manner; the first cast of the week is put down in a row of perhaps 150 to 200 yards in length, and the next day's cast is placed on the top of the first day's, and so on to the end of the week, when the pigs are cleared from top to bottom of the heap, thus giving a week's average of the iron, and preserving a uniform consistency and quality of steel.

"The productive capacity of the steel works is 3,500 tons per week. Rails constitute the principal branch of manufacture, there being three large rail mills, one plate mill, and one smaller mill for merchant steel. There are 18 convertors at work, and 12 steam hammers made by John Musgrave and Sons, of Bolton. One of the rail mills is driven by a Ramsbottom reversing engine. The other rail mills are on the three-high principle, and are worked by beam engines, supplied by Hick, of Bolton, while an ordinary horizontal engine, with a 40 inch cylinder, works the merchant mill. The total engine power of the works is equal to 4,000 horse power. Most of the boilers are of the ordinary Cornish pattern, but there are also 13 of Howard's patent boilers fired by "Vickers' mechanical appliance." It has been estimated that the Barrow furnaces produce upwards of a quarter of a

million tons of pig iron annually with a consumption of upwards of 370,000 tons of coal, and 470,000 tons of hematite.

"The Ironworks of the Wigan Coal and Iron Company at Kirkless consist of 10 blast furnaces, 5 being 65 feet high, and 5 80 feet high. Two of these latter are of recent construction, and are built upon the most improved principle. The furnaces have closed tops, and the gas is conveyed by a tube 8 feet in diameter to 18 double-flued boilers, 28 feet long and 7 feet 6 inches in diameter, which stand opposite the engine-house. The Wigan Company manufacture their own coke from the slack raised from their pits. At present there are 460 coke ovens, but the number is insufficient to supply the requirements of the furnaces. For some time past the slack after being washed has been crushed, which makes the coke much harder than formerly, and enables the furnaces to turn out more iron than under the old system. The crushing machines are of special construction, and were designed by the coke works manager. They are simple in design, and do their work regularly and efficiently. The works have ample waterway and railway accommodation. The canal immediately adjoins the works on one side, and they are also connected by private railways with the London and North-Western and Lancashire and Yorkshire Railways. The ore is brought in the railway waggons and emptied into bunkers running the whole length of the furnaces. The ore is taken from the bunkers in barrows, and with the coke and other materials used in the manufacture of iron is hoisted to the top of the furnaces by four vertical engines. About 400 men are employed at the furnaces, which manufacture four special brands, viz., the Kirkless foundry and forge, and the hematite and messelmoun brands. The engine-house stands at the end of the row of blast furnaces and is 100 feet long, 56 feet wide, and 70 feet high, with a tower 100 feet high. There are three pairs of compound engines, the high pressure cylinders being placed on one side of the building and the low pressure on the other, each pair being connected by a 36 foot beam. The high pressure cylinders are 45 inches, and the low pressure 66 inches in diameter, with a 12 foot stroke. The blowing cylinders, of which there are six, are each 100 inches in diameter. The steam pressure is 45 lbs., and the blast 3 lbs.

"The Wigan Coal and Iron Company have produced as much as 2,500,000 tons of coal and 150,000 tons of pig iron per annum.

The seams worked by the company include one of Cannel Coal, and also the well known Hartley Mine, and other portions of the Lancashire coal beds. The coking coal obtained from this district contains a certain percentage of sulphur, which if not removed or greatly reduced would render the coke unfit for producing the best marks of Bessemer pig, which forms the staple product of the company, and this has led to the extensive employment of coal washing machinery as already mentioned. The coal, after being crushed by crushing rollers, is lifted by elevators, and delivered into washing chambers or bashes, in each of which the water is made to rise and fall rapidly by the action of a piston working in a cylinder connected with the chamber, this piston being 36 inches in diameter, and making 150 strokes per minute. The length of stroke is 3½ inches. The coal rests on perforated copper sieves, and by the pulsating action of the water the good coal is washed over the edges of the sieves, while the pyrites being heavier, remain in the latter, and are removed at suitable intervals. The loss by washing is about 10 per cent., and the washed coal is coked in eight ton ovens, the coking process occupying five days. The iron ore used consists principally of the well known red hematite of the Ulverstone district, but a percentage of argillaceous Belfast ore is also employed for the purpose of bringing some alumina into the charge, thus forming a flux. Limestone is also added, the proportion of this latter material used when making Bessemer iron being very considerable."

Resuming with the production of pig iron in Lancashire the following shows the results attained since the year 1871:—

Year.	Furnaces.		Pig Iron made.	Average per Furnace.
	Built.	In Blast.		
	No.	No.	Tons.	Tons.
1872	41	34¾	524,041	15,080
1873	44	36	529,271	14,702
1874	47	33	488,672	15,800
1875	50	31	558,780	18,025
1876	50	30	552,984	18,432
1877	50	33	684,189	20,733
1878	50	30	616,255	20,542
1879	49	36	631,343	*17,537
1880	49	37	750,884	20,294

* The falling off in the average yield of the furnaces in 1879 is due to the fact that six of the furnaces were only in blast for a few months.

The furnaces of Lancashire work with great regularity, and when fully employed produce from 400 to 460 tons of iron weekly, of a quality suitable for conversion into steel by the Bessemer process. A glance at the returns of the past few years confirms the above statement. The following details illustrate clearly the proportion of the several parts of a furnace of the Furness Iron and Steel company at Askham, 67 feet in height, the capacity of which is 13,100 cubic feet:—

DESCRIPTION.	DIMENSIONS.
Height of furnace	67 ft.
Diameter at boshes	19 ,,
,, throat	18 ,,
,, hearth	7 ,,
Heating surface	5,500 sq. ft.
Number of tuyeres	6
Area of blast inlet	76 sq. in.
Pressure of blast at engine	2¾ lbs.
,, ,, tuyeres	3 ,,
Area of gas inlet	18 sq. ft.
Diameter of charging bell	12 ft. 6 in.
Weekly make of iron	400 to 460 tons.

The works and furnaces built and in operation in the year 1880 were as follows:—

LANCASHIRE.

No.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In Blast.
1	Barrow Hematite Iron & Steel	Barrow Hematite Steel Co., Lim.	14	13
2	Carnforth	Carnforth Hematite Iron Co., Limited	6	4
3	Darwen	Darwen Iron Co., Limited	2	2
4	Ditton Brook, Widnes	Ditton Brook Iron Co., Limited	6	3
5	Askam, Askam-in-Furness	Furness Iron & Steel Co., Lim.	4	3½
6	Kirkless Hall, Ince	Wigan Coal & Iron Co., Lim.	10	6
7	Newland Ulverston	Harrison, Ainslie, & Co.	2	1½
8	Backbarrow, ,,			
9	North Lonsdale, Ulverston	North Lonsdale Iron and Steel Co., Limited	4	3
10	Outwood, Ratcliffe	Outwood Iron Co., Lim.	1	1
		Total of Lancashire	49	37

Mills and Forges, and Steel Works.—In the year 1873 there were in Lancashire 23 malleable and six steel works, these latter making steel by the Bessemer process; the resources of the above 23 works numbered 350 puddling furnaces and 81 rolling

mills, the Bessemer plant amounting to 42 convertors of a united capacity equal to 228 tons, the annual consumption in all the above works in the year 1873 being estimated from reliable sources as 330,000 tons of coal. Already a brief account in a previous page described the Barrow Iron and Steel Works, the next most extensive steel works in the district are those of the Mersey Steel and Iron Company,* "situated near Liverpool, and covering an area of about eleven acres. These works comprise a plant of five pairs of six ton convertors, three pairs being arranged in one group, the other two pairs, each pair being placed by itself. Formerly the Mersey Steel and Iron Company were large steel manufacturers, and they were extensively engaged in the production of puddled steel prior to the development of the Bessemer process. For the past two years or so, however, they have discontinued the manufacture of steel rails, and their Bessemer plant has only been occasionally worked for the manufacture of the steel used for making the bars they are now using in the production of steel forgings."

"The ingot moulds used are all close-topped, and run from the bottom in groups, generally eight in a group. The central git used is of small diameter and is higher than the tops of the surrounding ingot moulds. The blowing engines connected with the Bessemer plant are contained in two engine-houses, one large engine-house adjoining the group of three pairs of convertors containing a pair of horizontal blowing engines by Messrs. Rothwell and Co., of Bolton, and also the engines for supplying water to the hydraulic cranes, &c., and three smaller blowing engines. In the other engine-house connected with the Bessemer department of the works, there is a pair of horizontal engines made by Galloways, of Manchester, which have piston valves on the blowing cylinders. To enable any pair of convertors to be blown from either engine, the air ways of the two engine-houses are connected."

"In the mill department there is a three high cogging-mill, a two high reversing rail mill used for bars, angles, and bull-headed rails. A new forge is now, however, in course of construction, to which the latter will be ultimately removed, and where also a three high cogging mill, driven by a pair of horizontal engines, and a two high reversing train driven by a pair of

* "Journal of the Iron and Steel Institute," 1879, p. 621.

vertical reversing engines, have been fitted up. Adjoining the forge are two machine shops, separated by the offices which stand between them—the one containing a good heavy plant of tools adapted for sharpening large forgings, such as stern posts, &c.—and includes an exceptionally large planing machine with two tables, which can either be run together or separately. The other machine shop is specially laid out for dealing with large crank shafts and contains an excellent plant for this purpose, including large lathes, and one of Messrs. Craven Brothers' crank pin turning lathes, in which the shaft to be turned is stationary, the tool being carried round it. The whole shop is commanded by a fine travelling crane worked by a fast running rope. In this division of the works, besides the forge and machine shops, there is a range of Siemens gas producers and a group of nine Lancashire steam boilers, for supplying steam to the steam hammers, &c. Passing through a tunnel another similar group of boilers is reached, these being adjacent to the engines of the steel works, but the steam pipes being connected, so that either division of the works can be supplied with steam from either group of boilers. The following is a list of the steel works employing the Bessemer process in Lancashire, distinguishing the number and capacity of the convertors":—

Name and Situation of Works.	Number of Convertors.	Capacity of Convertors.	
		Tons.	Cwts.
Carnforth Hematite Iron Co., Carnforth . .	2	6	0
Bolton Iron and Steel Co., Bolton . . .	4	5	0
Manchester, Sheffield, and Lincolnshire Railway Co., Gorton Works, near Manchester .	4	3	10
Mersey Steel and Iron Works, Toxteth Park, Liverpool	10	6	0
Manchester Steel and Railway Plant Co., Gibraltar Works, Newton Heath, Manchester .	4	3	0
Barrow Hematite Steel Co., Barrow . .	8	7	0

A careful examination of the quantity of fuel consumed in the iron and steel works in Lancashire for a few years, gives the following results. These figures are obtained from a large number of returns since the year 1871, and to render them available for comparison, the number of puddling furnaces and rolling mills in operation is given for each of the same years:—

Year.	Puddling Furnaces.	Rolling Mills.	Coal Used.
	No.	No.	Tons.
1873	350	81	330,000
1874	376	69	348,000
1875	434	69	465,455
1876	421	78	380,000
1877	389	77	363,125
1878	285	68	376,193
1879	353	82	542,247
1880	373	86	599,740

This description of the iron industries of Lancashire would be incomplete without the following list of mills and forges in the year 1880, which brings the information up to date:—

LANCASHIRE.

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Atherton Quay	Monks, Hall, & Co., Lim.	Warrington	26	3
2	Albion, Aspull	Edward Hale	Wigan	22	3
3	Atlas Forge	Thomas Walmsley & Sons	Bolton	16	12
4	Barrow	Barrow Hematite Steel Co., Limited	Ulverston	0	4
5	Bewsey	The Pearson and Knowles Coal and Iron Co., Lim.	Warrington	127	14
6	Dallam	"	"		
7	Moss Side	"	Wigan		
8	Bolton	Bolton Iron and Steel Co., Limited	Bolton	0	5
9	Bradford	Richd. Johnson and Nephew	Manchester	27	4
10	Carnforth	Carnforth Hematite Iron Co.	Carnforth	0	3
11	Garston	Liverpool and Garston Steel and Iron Co.	Garston	..	..
12	Gidlow	Thomas Gidlow	Wigan	..	..
13	Gibraltar	Railway Steel and Plant Co., Limited	Manchester	..	..
14	Globe	John Summers	Stalybridge	10	3
15	Gorton	M. S. and Lincolnshire Railway Co.	Manchester	1	3
16	Hartford Forge	Platt Brothers & Co., Limited	Oldham	8	3
17	Ince Hall	Ince Hall Rolling Mills Co., Limited	Wigan	24	4
18	Mersey	Mersey Steel and Iron Co., Limited	Liverpool	6	6
19	Openshaw	Ashbury Railway Carriage and Iron Co., Limited	Manchester	22	3
20	Park Bridge	H. Lees & Sons	Ashton	8	3
21	Pendleton	William Barningham & Co., Limited	Manchester	22	4
22	Perseverance, Pendleton	Maybury, Marston, and Sharpe	Pendleton	18	3
23	Preston	North of England Railway Carriage and Iron Co.	Preston	..	.
24	Wigan Rolling Mills	The Wigan Rolling Mills Co., Limited	Wigan	12	3
25	White Cross	White Cross Wire and Iron Co., Limited	Warrington	24	3
	Total of County			373	86

Coal and Iron Ore used in Manufacture.—The total quantity of pig iron made in the furnaces of Lancashire in the year 1872 was 524,041 tons, consuming in its manufacture 911,869 tons of coal and 998,000 tons of ore of all varieties. Since that year the following quantites show approximately the consumption of coal and iron ore in the manufacture of the crude metal:—

Year.	Pig Iron.	Coal Used.	Iron Ore Used.
	Tons.	Tons.	Tons.
1873	529,271	1,108,192	1,020,000
1874	488,672	930,849	895,130
1875	558,780	956,033	1,040,000
1876	552,984	991,377	1,029,000
1877	684,189	1,069,443	1,250,400
1878	616,255	1,044,114	1,143,351
1879	631,343	1,167,408	1,144,155
1880	750,884	1,362,154	1,344,093

An analysis of the above return for the year 1873 shows the actual quantity of coal used to each ton of pig iron made as averaging 42 cwts., all purposes included; this quantity is the equivalent of the coke, which is alone used in the Lancashire furnaces, where great economy is also secured in the utilization of the waste gases. Of the hematite smelted in Lancashire in the same year, Lancashire furnished 720,000 tons, Cumberland 128,960 tons, foreign ores principally from Spain and Elba 47,831 tons, and 123,209 tons made up of Cornish, Staffordshire red mine, the aluminous ores of Ireland, forge and mill cinder from the malleable iron works, and purple ore from the metal extraction works. The hematite ore was in the proportion of about 32 cwts. and of the other ores employed 7 cwts., in all 39 cwts. nearly of all kinds of ore to each ton of pig iron made, the proportion of coal as already stated being about 42 cwts.

In the following statement the source from whence the ore employed is derived appears, showing approximately the respective quantities:—

Description of Ore.	1876.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.
Hematite (Local) . .	862,870	1,028,426	946,351	965,580	1,226,163
Irish Ore	25,000	39,804	28,000	28,460	16,093
Foreign Ores . . .	28,000	36,900	35,000	24,538	34,669
Other Ores, &c. . .	112,530	165,270	134,000	123,577	67,168
Total . .	1,029,000	1,250,400	1,143,351	1,144,155	1,344,093

The hematite includes the produce of both Lancashire and Cumberland, the average produce of which may be taken as from 64 to 66 per cent. of metallic iron. It only remains to be observed that in recent years the quantity of ore employed, of all kinds, has not exceeded 37 cwts. to each ton of pig iron made. In the consumption of coal a marked economy appears in Lancashire; thus while in the year 1873 the average of coal used was 42 cwts., the returns for the years 1879 and 1880 show the average as not exceeding 37 cwts. and 36 cwts. of coal respectively to each ton of pig iron made in those years.

In some districts a far greater quantity is used, notably in those where cold blast iron is made, as in the West Riding of Yorkshire, where, in the year 1878, the average was 56 cwts., and in Scotland where raw uncoked coal is chiefly employed,—though not to such an extent as formerly,—49½ cwts. appear as the average, while in Lancashire as in Cumberland the rich Durham coke being principally employed the diminished consumption appears in the average of 36 cwts. in Lancashire and 39 cwts. in Cumberland to each ton of pig iron made in the year 1880.

CHAPTER VI.

CHESHIRE IRON INDUSTRIES.

Description of the Engineering and Metallurgical Works of the London and North-Western Railway, Crewe.

The Iron and Steel Industries.—The great engineering and metallurgical works of the London and North-Western Railway at Crewe call for a brief notice. They have the reputation of being the largest in the world, comprising steel works in which the Bessemer and Siemens processes for the manufacture of steel are employed on a large scale. The Crewe works were projected in 1843 for the purpose of repairing the locomotives of what was at one time the Grand Junction Railway; some years later machinery for the manufacture of rails was introduced, and when in the year 1857 the amalgamation of the Northern with the North-Eastern division of the system took place, the works at Crewe became the centre of the locomotive and carriage departments of the northern division of the line. In 1864 works were erected for the manufacture of steel by the Bessemer process, and about 1870 an open hearth steel-making plant was added, which has since been largely used in the production of steel for locomotive purposes.

Upwards of 2,000 locomotives have been made at the Crewe works, and as many as 146 in one year. No other works in the world have made and used steel so extensively for railway purposes. The works as a whole cover an area of 27 acres, and employ over 5,000 hands. The Bessemer Steel Converting Works consist of four 5-ton convertors. The pig-iron is first melted in an ordinary cupola, to which the air is supplied by a Roots Blower, whence it is run into one of the converting vessels; the air is supplied to the converting vessels by a pair of horizontal blowing engines of 440 horse-power. The cogging mills, tyre-rolling mills, plate-rolling mills, merchant mills, and mills for rolling spring steel, &c., possess all the modern improvements

and are complete in every mechanical arangement. The boiler department is a very important branch of the works; here a building 300 feet long and 107 feet wide is devoted to the manufacture of boilers for locomotive and stationary purposes, the material employed being steel.

The great requirements of the London and North-Western Railway may be gathered from the extent of its permanent way, and the rolling stock necessary for the efficient carrying out of its passenger, mineral, and general traffic. It was recently stated by Mr. F. W. Webb, the manager of these works : That if the engines and tenders of the Company were extended in line they would reach a distance of 18 miles; the carriages would occupy 30 miles, and the waggons 130 miles, or nearly the distance between the works at Crewe and London. The resources of the Company are such that on a recent occasion they had turned out a complete engine, ready for the steam, in the short time of 25 hours and a half.

CHAPTER VII.

DERBYSHIRE IRON INDUSTRIES.

Description of Ironstones of the Coal Measures—Analyses and production of Ironstone—Pig Iron Manufacture in Derbyshire and Nottinghamshire—Early History of the Industry—Production and Works in operation—Malleable Iron Works in 1811—Puddling Furnaces and Rolling Mills in recent years and Coal consumed—Coal and Iron Ore used in Pig Iron Manufacture—Districts furnishing Iron Ore.

Ironstones of the Coal Measures.—The southern extension of the Great Midland Coal-field, in the counties of Derby and Nottingham, like the northern division in the West Riding of Yorkshire, is equally rich in its resources of coal measure ironstone; but while the beds of coal throughout the area present more or less regularity in regard to thickness and production, the measures of ironstone, on the other hand, exhibit much irregularity in thickness, frequently thinning out within comparatively short distances. In the northern division of the Great Midland Coal-field, in the West Riding of Yorkshire, the two principal seams of coal, at the top and bottom of the coal-measures, are known as the "Barnsley" and the "Silkstone" seams, between which are distributed, interstratified with less important seams, numerous measures or bands of ironstone, especially the Low Moor beds immediately north of Leeds.

The principal seams of coal in the Wentworth district, near Rotherham, have a thickness, the former varying from 6 feet to 9 feet 6 inches, while the latter is four feet. In Derbyshire the "Barnsley" and "Silkstone" seams are identified respectively as the "Top Hard" and "Black Shale," or Clod Coal, the first-named seam at Staveley, near Chesterfield, being 6 feet, and the latter 5 feet thick. Between these seams of coal in Derbyshire, as in Yorkshire, the more important measures of ironstone occur. In Derbyshire these measures are known as "Rakes," in which the ironstone is distributed in the form of nodules, frequently lying in such thickness as only to be wrought

to advantage by open workings, or, as they are locally called, "Bell Pits." Where such a mode of working is adopted a considerable production of ironstone is secured. The following are the more important ironstone measures in Derbyshire, occurring in descending order between the "Top Hard" and "Black Shale" seams of coal:—

The uppermost of these measures is known as the "*Buff or Cement Rake*" in the Alfreton district, consisting of three bands in a section of 9 feet, and yields 1,800 tons of ironstone per acre. The "Pinder Park Rake" at Staveley, also consisting of three bands in a section of 6 feet, yields of ironstone 2,000 tons per acre, while the "Brown Rake" at Butterley, in the Alfreton district, yields 2,500 tons per acre.

The "*Black Rake*" measure also in the same district and below the "Brown Rake," consisting of five courses or bands, yields 2,000 tons per acre.

The "*Dog Tooth Rake*" next occurs, consisting at Staveley of 5 measures in a section of 8½ feet, and yielding 2,000 tons of ironstone per acre. This important measure, well exposed in a section at Unstone near Dronfield, shows the annexed succession of strata with Gray Shale and ironstones of the open workings in that neighbourhood:—

SUCCESSION OF STRATA.

	Ft.	In.
Dog Tooth measure	24	0
Bearstone or band of cone-in-cone structure	0	9
Shales	9	0
Blueish bind with two courses of ironstone	4	0
Coal	1	2
Hardfloor with Stigmariæ abundant, very similar to Ganister	1	0
Fire clay	4	0
Coal	1	9

At Butterley this same ironstone is known as "Wallis's Rake," south of which it does not prove. Below occurs the "Nodule Rake," at Morley Park, yielding 1,600 tons per acre; south of Clay Cross it is known as the "Dog Tooth Rake," below which the most productive ironstone measure in the district occurs, the "Black Shale Rake" consisting of 16 bands. In the neighbourhood of Chesterfield these bands are divided into top and bottom measures by 12 feet of bind. The Black Shale Rake here yields from 4,000 to 7,000 tons of ironstone per acre. Another measure

below, known as the "*Striped Rake,*" at Kirk Hallam, yields 2,500 tons per acre.

The "*Black Shale*" coal occurs some 16 feet below, having a thickness of five feet, below which and before the millstone grit is reached, a series of beds occurs, known as the Ganister series, of considerable thickness. In the upper part of this series, and before the Kilburne coal is reached, are some bands of ironstone, principally worked in the districts of Morley Park and Alfreton; they are known as the "Green Close Rake" and the Holly Close Rake," yielding from 1,000 to 1,200 tons per acre. The "Black," or "Kellands Rake," at Morley Park, and the "Yew Tree Rake," yielding respectively 3,000 tons and 1,000 tons per acre.

Below the Kilburne coal which here occurs appear the "Honey-croft Rake" and the "Civilly Rake," the former consisting of 8 bands, and at Stanton yielding 6,000 tons, the latter of 5 bands, and yielding in the same neighbourhood 4,000 tons of ironstone per acre; while the "Dale Moor Rake," a measure of 5 bands occurring below the Furnace Coal (a seam 2 feet 3 inches thick), yields 3,000 tons per acre of ironstone.

The total thickness of the measures above enumerated is 1,600 feet, to which may be added 400 feet for the strata occupying the several seams of coal and ironstone.

Analyses of the Ironstone.—Very complete analyses of the ironstone measures worked in Derbyshire, in the Butterley and Staveley districts, have been published in the Memoirs of the Geological Survey of Great Britain.* The "Brown Rake" of Butterley is described as follows, and generally illustrates the character of the other measures of the district:—"Colour, pale brownish-grey, inclined to red in some parts from peroxidation; very thin seams of a bluish shale are irregularly interstratified with the ore; fracture usually rough." A second variety of the same measure is described as "Colour blackish-grey, of various degrees of intensity, in irregular bands parallel to the plane of stratification. The ore containing an abundance of fossil shells incrusted with ochrey peroxide of iron." These ores, and others in the annexed table, in the Butterley district, consisted of equal weights of two ores selected for analysis, and are thus constituted:—

* "Iron Ores of Great Britain," Part I. (out of print), 1856.

RESULTS TABULATED.

Constituents.	Brown Rake.	Brown Rake.	Black Rake.
Protoxide of iron	37·99	35·74	33·56
Peroxide of iron	1·04	1·26	1·66
Protoxide of manganese	1·51	1·23	0·96
Alumina	0·41	0·47	0·73
Lime	4·53	2·94	3·02
Magnesia	3·30	2·70	2·81
Carbonic acid	29·92	26·74	25·63
Phosphoric acid	0·80	0·66	0·79
Sulphuric acid	trace.	trace.	trace.
Bisulphide of iron	0·06	0·05	0·26
Water hygroscopic	0·74	0·68	0·74
,, combined	1·47	1·49	1·51
Organic matter	1·42	0·76	1·57
Insoluble residue	16·35	24·83	26·46
	99·54	99·55	99·70
INSOLUBLE RESIDUE.			
Silica	10·04	16·07	17·13
Alumina	5·16	6·62	7·76
Peroxide of iron	0·45	0·92	0·50
Lime	0·06	0·07	0·15
Magnesia	0·07	0·26	0·25
Potash	0·55	0·66	0·74
	16·33	. 24·60	26·53
Metallic iron	30·60	29·32	27·61

A note appended to these analyses states that in the first a trace of reddish metal, too small to examine, was detected in 1,200 grains of the ore, while as regards the others, distinct traces of lead and copper were found in 600 grains of the one and 700 grains of the other.

The measures wrought in the Stanton district are thus described :—" The Swallow Wood Rake" easily scratched, light drab in colour, one sample a shade darker; all have a rough non-crystalline fracture, and are readily reduced to powder. The sample analysed consisted of equal weights of three of the ores.

The "Honeycroft Rake," of Stanton, examined by Mr. John Spiller, consisting of eight bands of the measure, the sample taken for analysis consisting of equal weights of the several ores.

The "Civilly Rake" and the "Dale Moor Rake," the former

consisting of five measures and the latter a similar number, equal parts of each in weight being taken for analyses. The results given are as follows:—*

RESULTS TABULATED.

Constituents.	Swallow-wood Rake.	Honeycroft Rake.	Civilly Rake.	Dale Moor Rake.
Protoxide of iron	33·72	40·01	33·31	39·55
Peroxide of iron	...	1·60	1·47	2·71
Protoxide of manganese	1·01	1·26	2·18	1·50
Alumina	0·67	0·58	0·95	1·14
Lime	3·99	2·78	2·32	3·32
Magnesia	5·43	2·88	2·44	2·85
Carbonic acid	28·64	29·72	24·83	28·63
Phosphoric acid	0·41	0·34	0·62	1·12
Sulphuric acid	trace.	trace.	trace.	trace.
Bisulphide of iron	0·13	0·09	0·13	0·05
Water hygroscopic	0·57	0·45	0·70	0·51
,, combined	0·87	1·12	1·87	1·24
Organic matter	0·36	1·38	1·85	1·14
Insoluble residue	23·55	17·84	27·42	15·80
	99·35	100·05	100·09	99·56
INSOLUBLE RESIDUE.				
Silica	16·02	11·19	17·24	10·22
Alumina	5·74	5·33	7·90	4·51
Peroxide of iron	0·79	0·70	1·22	0·78
Lime	trace.	trace.		0·06
Magnesia	0·06	0·17	0·27	0·03
Potash	0·47	0·34	0·49	0·48
	23·08	17·73	27·12	16·08
Iron, total amount	26·79	32·73	27·79	33·20

Notes appended to these analyses state that none of the metals, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, were detected in 560 grains of ore of the Swallow Wood Rake; minute traces of copper were found in the other samples, with the addition of zinc blends in the Dale Moor Rake.

The "Dog Tooth Rake," extensively worked in the neighbourhood of Staveley, is also reported upon in the "Iron Ores of Great Britain." The ironstones are described as of the same colour, light brownish-grey, rough in fracture, easily scratched

* "Iron Ores of Great Britain," Part I., pp. 78, 90, 92, and 94.

by a steel point. Another variety contains a few shells irregularly diffused. The second analysis of the ironstone of the same measure, described as a "Clay ironstone," consisting of two samples, both light brownish-grey in colour, and containing abundance of fossil shells, which in the case of one sample are large and confusedly packed together, though generally lying parallel to the plane of stratification; while in the other they occur as a more irregular deposit made up in part, apparently, of fragments of shells. The hardness of the ore is such that they are not easily scratched by a steel point; fracture compact and irregular, the surface of fracture being influenced by the position of the contained shells. In each analysis the sample consisted of a mixture of the two ores in equal weights :—*

RESULTS TABULATED.

Constituents.	Dog Tooth Rake. Staveley.	Dog Tooth Rake. Staveley.
Protoxide of iron	38·97	28·27
Peroxide of iron	0·88	1·01
Protoxide of manganese	1·09	1·02
Alumina	0·38	0·33
Lime	1·58	13·94
Magnesia	4·62	9·18
Carbonic acid	30·14	37·61
Phosphoric acid	0·48	0·74
Sulphuric acid	trace.	trace.
Bisulphide of iron	0·05	0·04
Water hygroscopic	0·64	0·18
,, in combination	1·02	0·73
Organic matter	0·30	0·92
Insoluble Residue	19·10	6·39
	99·25	100·36
INSOLUBLE RESIDUE.		
Silica	11·90	3·55
Alumina	5·55	1·98
Peroxide of iron	0·59	0·41
Lime	0·04	trace.
Magnesia	0·20	0·09
Potash	0·67	0·16
	18·95	6.19
Metallic iron	31·34	22·98

* "Iron Ores of Great Britain," Part I., pp. 86, 88.

A note appended to the first analysis states that a minute trace of copper was found in 630 grains of the ore, and that a minute trace of a white metal, too small to examine, was found in the second in 460 grains of the ore.

Taking an average of the amount of metallic iron contained in the foregoing analyses, 29·15 per cent. will fairly represent the yield of the ironstone of Derbyshire. In the annexed table is given the several ironstone measures above enumerated, the analyst, and percentage of metallic iron in each :—

Ironstone Measures.	Analyst.	Iron per Cent.
Brown Rake (Butterley)	Mr. John Spiller	30·60
Brown Rake ,, ...	,,	29·32
Black Rake ,, ...	,,	27·61
Swallow Wood Rake (Stanton) .	,,	26·79
Honeycroft Rake ,, . .	,,	32·73
Civilly Rake ,, .	,,	27·79
Dale Moor Rake ,, . .	,,	33·20
Dog Tooth Rake (Staveley) . .	,,	31·34
Dog Tooth Rake ,, . .	,,	22·98

Production of Ironstone.—The yield of the ironstone measures of Derbyshire has been as follows since the year 1855 :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1855	409,500	1868	368,440
1856	392,400	1869	352,072
1857	350,000	1870	384,865
1858	328,950	1871	492,973
1859	325,500	1872	307,183
1860	387,500	1873	365,127
1861	396,520	1874	239,292
1862	345,450	1875	218,132
1863	350,500	1876	199,908
1864	325,600	1877	206,247
1865	350,000	1878	175,260
1866	329,500	1879	146,341
1867	350,000	1880	150,248

The quantity raised in the year 1880 amounted to 150,248 tons, of the average value of 10*s*. per ton. The quantities raised in 1873 and 1874 (the last detailed returns published), when the average value was 12*s*. per ton, was obtained in the localities named are given on the next page :—

District or Mine.	1873. Quantities.	1874. Quantities.
	Tons.	Tons.
Alfreton	14,854	...
Blackwell	...	300
Butterley	71,165	55,439
Clay Cross	...	794
Morley	13,353	...
Renishaw	10,500	...
Riddings	...	13,754
Staveley	173,664	19,511
Sheepbridge	12,446	13,077
Wingerworth	14,771	...
West Hallam	18,917	2,417
Sundry pits	35,457	134,000
Total	365,127	239,292

Derbyshire (including Nottinghamshire): Pig Iron Manufacture.—The smelting of the ores of iron in Derbyshire with coke dates from about the year 1780; previously numerous small bloomaries existed in various districts, where cast and bar iron were made with charcoal, but these gradually disappeared, and in the year 1788 the last ceased working. The blast at these works was secured by means of a water-wheel. With the use of coal or coke a great change took place in the form and construction of the blast-furnace; hitherto when charcoal was employed, they were square in form, subsequently those erected were circular and of increased height and capacity. With these changes came most opportunely the improvement in the steam-engine by Mr. James Watt, which our ironmasters were not slow in adopting, and thus considerably and in a very short period increased the productive power of their establishments.

In the year 1740 there appear to have been two furnaces in Derbyshire, making charcoal pig iron to the amount of 550 tons or 225 tons per furnace. The first furnace erected in Derbyshire in which coke was exclusively employed in the make of pig iron was at Morley Park in the year 1780, where also a few years later the steam-engine was successfully introduced, in working the blast the original proprietor being a Mr. Francis Hurt; these works were succeeded in the same year by two others situated at Chesterfield, known as the Griffin, or New Brampton, and the Stone Gravel, located on the Chesterfield Canal. The first-named works were projected by Messrs. E. Smith and Co., and the latter by Messrs. Smith and Armitage. The works at Winger-

worth followed by Mr. Joseph Butler, and in 1786 the Staveley Works commenced operations by Messrs. Ward and Low. In 1788 works were established at Dale Abbey by Messrs. English and Co., which a few years later were dismantled and subsequently pulled down. The year 1792 was marked by the establishing of the Butterley and Renishaw Works by Messrs. Outram & Co., at Eckington, and Messrs. Appleby & Co. at Alfreton, and these were succeeded by others; the Alfreton Works by Messrs. Oakes, Edwards, & Co., at one time known as the Somercotes Works, and situated on the banks of the Cromford Canal; the Hasland, or Grass Hill, by Mr. John Brocksop, and in 1799 the Duckmanton (or Adelphi) Works by Messrs. Smith & Co.; the two last-named works have long since been abandoned and dismantled. It was at the Somercotes Works above referred to that Mr. David Mushet introduced his system of making coke on a large scale for the blast furnace, known as the "Close Way," as distinguished from the old method in use at the beginning of the present century, of making a large heap of coals, which being set fire to, were subsequently extinguished by a stream of water when the coking was complete.

The make of charcoal pig iron in Derbyshire in the year 1788 by the only remaining charcoal furnace at Wingerworth, is stated to have been 300 tons. In the same year 7 furnaces producing coke pig iron in Great Britain made 4,200 tons, giving an average per furnace of 600 tons.

Advancing to the inquiry instituted by Dr. MacNab for the year 1796, it appears that the make of pig iron in Derbyshire in that year amounted to 9,656 tons. The following is a list of the works then in operation, with the number of furnaces and the yield of pig iron:—

Works.	Furnaces.	Pig Iron.
		Tons.
Butterley	1	936
Chapel	1	1,456
Chesterfield	1	940
Dale Abbey	1	443
Little Brampton	2	1,560
Morley Park	1	728
Renishaw.	2	705
Staveley	1	761
Park	1	853
Wingerworth	1	1,274
Total	12	9,656

The total make of pig iron in Great Britain was, according to MacNab's inquiry, 125,079 tons, there being in the same year 124 furnaces in operation.

Farey, in his "Survey of Derbyshire," written in the beginning of the present century, gives a very complete account of the works and furnaces built and in operation in the year 1806, with the individual production of coke pig iron in each works as follows :—

Works.	Furnaces. Built.	Furnaces. In Blast.	Pig Iron Made.
			Tons.
Alfreton	1	1	1,450
Butterley	2	2	1,766
Chesterfield (Griffin)	3	2	1,700
,, (Stone Gravel)	2	1	700
Dale Abbey	1	...	...
Duckmanton	2	1	900
Hasland	1	1	723
Morley Park	1	1	700
Renishaw	2	1	975
Staveley	1	1	596
Wingerworth	2	1	819
Total	18	12	10,329

The make of coke pig iron in Great Britain in 1806 was 250,406 tons, and of charcoal pig iron 7,800 tons, giving a total production of 258,206 tons of pig iron, which, when compared with the production of the year 1788, shows an increase fourfold.

The Butterley Company about the year 1811, extended their powers of production by the erection of the Codnor Park Works with two blast furnaces, to which a third was added in the year 1825. This Company has long been celebrated for its massive and magnificent castings, examples of which may be seen in the iron bridge over the River Thames at Vauxhall, the colonnade in front of the Opera House in the Haymarket, and in numerous bridges and roofs in the West India and other docks; while north of the Tweed, the bridge at Leith Harbour and others, and lock-gates on the Caledonian Canal may be referred to. The next account of pig iron manufacture in Derbyshire is for the years 1823 and 1830, prepared by Mr. Frederick Finch, who ascertained that the make of 15 furnaces in the year 1823 amounted to 14,038 tons; and in the year 1830, of 18 furnaces, to 17,999

tons, showing an increase in the seven years of 3,961 tons or 28 per cent.

The details of Mr. Finch's returns for Derbyshire appear in the annexed statement, with the number of furnaces in each works, and the make of pig iron :—

Works.	1823.		1830.	
	Furnaces.	Pig Iron.	Furnaces.	Pig Iron.
		Tons.		Tons.
Alfreton	2	2,690	2	2,950
Brampton	2	1,807	2	1,245
Butterley	3	2,639	3	3,981
Calow	1	...	1	123
Codnor Park	2	2,096	3	2,455
Duckmanton	1	1,091	1	1,446
Morley Park	1	544	2	1,428
Renishaw	2	2,120	2	2,810
Staveley	1	1,051	2	1,561
Total	15	14,038	18	17,999

Advancing to the year 1839, when Mr. David Mushet gave the production of pig iron as 1,248,781 tons, the make of 378 furnaces; the Derbyshire furnaces, of which 14 were in blast, produced 34,372 tons. Again in the years 1840 and 1843, the respective production amounted to 1,396,400 tons and 1,215,350 tons, of which Derbyshire contributed respectively 31,000 tons and 25,750 tons.

The late Mr. Samuel H. Blackwell, in the year 1851 entered very fully into the iron making resources of the United Kingdom, and furnished the following list of works in Derbyshire, the number of furnaces built and in blast, and the production of pig iron, amounting to 60,000 tons :—

Works.	Furnaces.		Works.	Furnaces.	
	Built.	In Blast.		Built.	In Blast.
Alfreton	3	2	Newbold	1	1
Brimington Moor	1	1	Renishaw	2	1
Butterley	3	2	Stanton	3	2
Codnor Park	2	2	Staveley	4	2
Clay Cross	2	1	Unstone	1	1
Duckmanton	1	0	West Hallam	2	1
Morley Park	2	2	Wingerworth	2	1

The average yield of the furnaces at this period was 3,158 tons per annum.

In subsequent years the production of the Derbyshire furnaces appears as follows, and for comparison it will be convenient to give side by side the production of the furnaces in the West Riding of Yorkshire (which occurs within the area of the northern division of the Great Midland Coal-field of Yorkshire, Derbyshire, and Nottinghamshire) :—

Year.	Furnaces.		Derbyshire.	W. Riding of Yorkshire.
	Built.	In Blast.	Pig Iron.	Pig Iron.
			Tons.	Tons.
1855	33	24	116,550	90,840
1856	33	26	106,960	96,200
1857	34	25	112,160	117,000
1858	34	28	131,577	85,936
1859	36	27	139,250	84,950
1860	37	23	125,850	98,100
1861	37	24	129,715	142,865
1862	44	32	131,005	112,121
1863	42	31	170,026	104,745
1864	43	31	174,743	102,093
1865	41	34	189,364	123,233
1866	42	33	199,867	119,747
1867	43	30	160,028	109,002
1868	42	28	159,312	100,050
1869	43	31	188,353	105,765
1870	43	30	179,772	77,717
1871	46	38	270,485	114,549
1872	46	38	283,375	148,636
1873	47	39	296,468	151,511
1874	50	38	301,687	163,856
1875	51	38	272,065	267,153
1876	54	35	300,719	235,451
1877	53	47	328,203	229,027
1878	55	38	306,141	219,547
1879	53	35	291,455	218,805
1880	54	40	366,792	306,560

Taking the average yield of the furnaces in Derbyshire, a steady increase appears; thus, in 1855, the average was 4,856 tons, increased to 5,428 tons in 1860, and 5,570 tons in 1865; again, in 1870, the average was 5,992 tons; in 1875, 7,160 tons, and in 1880, 9,169 tons, comparing favourably with the year 1851, when the average was but 3,158 tons per furnace.

The respective works and firms, with the numbers of furnaces built and in blast in the year 1880, were as follows :—

DERBYSHIRE.

No.	Name of Works.	Owners.	Furnaces built.	Furnaces in blast.
1	Alfreton	James Oakes & Co. . . .	3	3
2	Butterley, Alfreton . . .	The Butterley Co. . . .	3	1
3	Codnor Park	,, ...	4	2
4	Clay Cross	The Clay Cross Co. . . .	·3	3
5	Denby, Derby . . .	George Dawes	4	3
6	Morley Park, Belper . .	Henry Cathrow Disney . .	2	0
7	Newbold, Chesterfield . .	Newbold Iron and Coal Co. .	1	0
8	Renishaw, Eckington . .	F. R. Appleby & Co. . . .	3	3
9	Sheepbridge, Chesterfield .	Sheepbridge Coal and Iron Co., Limited * . . .	6	5
10	Stanton, Nottingham . .	Stanton Iron Works Co. . .	8	7
11	Staveley, Chesterfield . .	Staveley Coal and Iron Co., Limited	8	7
12	West Hallam, Ilkeston . .	West Hallam Coal and Iron Co.	2	1
13	Wingerworth, Chesterfield .	Wingerworth Iron Co., Limited	3	3
14	Erewash Valley, Ilkestone .	Erewash Valley Iron Co. . .	4	2
		Total	54	40

Mills and Forges.—Farey, in his "Survey of Derbyshire," published in 1811, states that "Until about forty years ago (1771) small furnaces and bloomaries, heated by charcoal, were alone used, for the making of either cast or bar iron in these districts. At Wingerworth one of these charcoal furnaces continued in some use, blown by means of a water-wheel, until the year 1784; this work, or others on the site of it, having been used for more than 180 years; and at Walley in Bolsover another was used until about the year 1770." Farey gives a list of 23 localities, where he had observed the slag and remains of old bloomaries and charcoal furnaces, and he further supplements the list by another, of the forges and puddling works where bar iron was made in Derbyshire and adjoining counties as follows :—†

MILLS AND FORGES IN DERBYSHIRE.

Alderwasley, near Wirksworth (two formerly); Francis Hurt.
Brightside, near Attercliffe, Yorkshire; late Swallow & Co.
Bugsworth, in Glossop.
Chapel-en-le-Frith.
Chapel Mill-town.
Chesterfield (New Brampton); Ebenezer Smith & Co.
Clay Mills, near Burton (on the Dove), Staffordshire.
Codnor Lower Park (now erecting); Butterley Co.
Killamarsh; Joseph Butler.
Makeney in Duffield (disused).
Rotherham; Walker & Co.
Sheffield Town; Samuel Smith & Co.
,, Shelton & Co.
Staveley; Ward & Barrow.
Wichnor, near Burton, Staffordshire; Thornywell & Co.
Winshill, in Stapenhill (disused).

* Two furnaces building. † Farey's "Derbyshire," 1811, vol. i., p. 403.

Farey* further adds that at "most of the above works they have large rolling and slitting apparatuses, for making plate iron, or bars of different sizes, down to the smallest nail rod; besides which, there are rolling and slitting mills for such purposes in Derbyshire, in All Saints in Derby, and at Burrowash in Ockbrook."

For many years these works have been as follows, with the respective firms, while, from time to time, their powers of production have been increased in the number of puddling furnaces and rolling mills to meet the demands of trade. These works stood as under in the year 1880:—

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Butterley . . .	The Butterley Co. . .	Alfreton . .	40	7
2	Railway (Litchurch)	Eastwood, Swingler & Co.	Derby . .	36	2
3	Victoria . . .	,,	,, . .		
4	Whittington . .	Thomas Firth & Sons .	Chesterfield . .	17	3
5	Sheepbridge . .	Sheepbridge Coal and Iron Co., Limited	,, . .	8	2
	Total . .	. . . . . .	. . . . . .	101	14

Of the coal consumed in these malleable iron works the quantities in each of the years 1872 and 1873 did not exceed 130,000 tons, including all the purposes where coal was employed. In recent years the following quantities show the consumption, all purposes included:—

Year.	Coal Used.	Year.	Coal Used.
	Tons.		Tons.
1873	130,000	1877	85,000
1874	96,350	1878	80,487
1875	90,879	1879	82,466
1876	83,989	1880	90,178

Coal and Iron Ore used in Manufacture.—Taking up inquiries on this subject with the year 1840, when Mr. William Jessop of the Butterley Ironworks made a searching investigation on the subject, it was ascertained that four tons of coal were employed in the manufacture of each ton of pig iron. At this period the average quantity used in Great Britain was 3½ tons of

* "General View of the Agriculture and Minerals of Derbyshire." John Farey, 1811.

coal to each ton of pig iron. The total quantity of coal used in Derbyshire in the year 1840 was 129,000 tons in the manufacture of 31,000 tons of pig iron. It is recorded in the pages of the Royal Coal Commission, that in the year 1869 the quantity did not exceed 3 tons, while in the year 1872 it had further diminished to 58 cwts. of coal to each ton of pig iron. The total quantities of coal and iron ore used in each year since 1872 appears as follows, together with the quantities of pig iron made:—

Year.	Pig Iron.	Coal Used.	Iron Ore Used.
	Tons.	Tons.	Tons.
1872	283,375	821,833	745,560
1873	296,468	865,350	775,000
1874	301,687	905,951	788,500
1875	272,065	779,100	715,648
1876	300,719	777,772	774,824
1877	328,203	869,368	875,573
1878	306,141	793,028	833,109
1879	291,455	765,821	799,280
1880	355,603	935,913	1,027,657

Thus, in the year 1872, when the average consumption of coal in Great Britain in the manufacture of iron was 51 cwts. to the ton; the average in the Derbyshire furnaces was about 58 cwts. The increased economy of coal since that date has been considerable, the average in 1877 being 53 cwts., in 1878 but 51½ cwts.; while in the year 1879 it shows an increase, the average being 52½ cwts. In the same way the average coal used throughout the kingdom in iron-making compares favourably in each of the same years, decreasing from 51 cwts. in the year 1872 to 44¾ cwts. in the year 1878, and about 43 cwts. in the year 1880, when the total quantity of coal used in the smelting of iron ore in Great Britain was 16,682,629 tons.

The bulk of production of the clay ironstone measures of Derbyshire is smelted in the furnaces of Derbyshire. The ironstone when used in the raw state requires 54 cwts. to each ton of pig iron made, the Derbyshire stone containing from 22·98 to 33·20 per cent, of metallic iron. Large quantities of iron ore are imported into the country to meet the requirements of the ironmaster, principally from Northamptonshire and Lincolnshire, and also from more distant places not separately ascer-

tained. These ores being more rich in metallic iron than the native-mine, are in good request and are advantageously employed.

The iron ores employed in the furnaces in the year 1874 and two preceding years were derived from the following districts :—

Districts.	1872.	1873.	1874.
	Tons.	Tons.	Tons.
Derbyshire	317,560	320,000	305,350
Northamptonshire . . .	290,500	308,700	313,924
Lincolnshire	1,500	2,500	3,326
Other places	136,000	143,800	165,900
Total	745,560	775,000	788,500

The ores in the last-named quantities are probably derived from Lancashire and Cumberland.

The Derbyshire ironstone, by calcination, may be said generally to lose about one-third of its weight, and it appears that as early as the beginning of the present century, according to Farey,* "that this system of concentrating the metal in the ore was carried out in Derbyshire at Somercotes, and some other works, where the ore was roasted in kilns similar to lime-kilns, with considerable saving of time and of coals, but, it is said, with some increased loss of ore, in being crushed to pieces in passing through the kiln, to what happens in the open heaps, like coke-heaps, in which it is usually wasted; for pieces of roasted iron ore smaller than peas cannot be admitted into the furnace for fear of choking it. The small ore thus sifted out is called *Minion* and is thrown away, or used for making paths in gardens, &c., in which situation it sets hard and firm."

Returning to the quantities of iron ore supplied to the blast furnaces of Derbyshire, the annexed table gives the districts furnishing the same, and the approximate quantities :—

Districts.	1876.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.
Derbyshire	220,000	238,900	215,000	180,000	165,000
Northamptonshire . .	494,402	514,803	521,308	507,226	696,903
Lincolnshire	6,508	8,760	7,783	7,434	11,826
Other places . . .	53,914	113,110	89,018	104,620	153,928
Total. . .	774,824	875,573	833,109	799,280	1,027,657

* Farey's "Derbyshire," vol. i., p. 401.

CHAPTER VIII.

NOTTINGHAMSHIRE AND WARWICKSHIRE IRON INDUSTRIES.

Ironstone of the Coal Measures—Analyses and Production.

Nottinghamshire.—*Production of Ironstone.*—The quantities raised from the ironstone measures in Nottinghamshire have not at any time been considerable; in 1874 there were but 228 tons returned, the value of £186 being given. Since that date the returns have been as follows, with the values in each year:—

Year.	Quantities.	Value.
	Tons.	£
1875	11,750	7,543
1876	15,406	9,243
1877	16,986	10,191
1878	12,250	6,125
1879	20,000	10,000
1880	2,264	1,132

These values show an average price per ton, in 1875, of 12*s*. 9*d*., receding to 12*s*. in 1877, since which date 10*s*. has been the average.

Warwickshire.—*Analysis of Ironstone.*—The argillaceous ores obtained from this coal-field vary like others in the percentage of iron which they contain. The ironstone obtained from the Bedworth district, near Coventry, may be taken as characteristic of the best description of ores of this class. The annexed analysis shows the composition of the Bedworth ironstone above referred to.*

* Mr. S. H. Blackwell's "Iron making Resources of the United Kingdom." Lecture, Society of Arts, 1851, p. 151.

RESULTS TABULATED.

Carbonate of iron	79·19
Carbonate of manganese	1·45
Carbonate of lime	5.85
Carbonate of magnesia	6·30
Alumina	0·50
Silica	4·85
Phosphoric acid	0·71
Water, bituminous matter, and loss	1·15
	100·00

These argillaceous ores usually contain from 30 to 35 per cent., the better varieties ranging as high as 40 per cent., and are but in little demand when found to contain less than from 25 to 30 per cent. of metallic iron. The above example gives 37·88 per cent.

Production of Ironstone.—But little information on this subject appears before the year 1858. In that year the quantity of ironstone obtained amounted to 29,500 tons, valued at £11,060, giving an average of about 9*s*. per ton. In subsequent years the argillaceous ore of Warwickshire yielded the following quantities and value :—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1859	30,500	10,500	1870	17,500	6,125
1860	19,500	5,025	1871	34,075	15,570
1861	15,250	4,000	1872	43,375	16,246
1862	14,750	3,678	1873	43,837	26,302
1863	12,500	3,150	1874	92,214	39,528
1864	15,750	3,939	1875	97,456	48,720
1865	16,500	4,128	1876	92,838	46,419
1866	18,750	4,687	1877	79,965	47,979
1867	15,500	3,878	1878	57,222	28,611
1868	14,795	3,698	1879	16,214	8,107
1869	15,000	3,750	1880	36,972	18,486

For many years the average price of these ores did not exceed 5*s*. per ton; about 1870 they rose to 7*s*., and in 1874 to 10*s*. per ton, since which date they have shown but little variation.

CHAPTER IX.

SHROPSHIRE IRON INDUSTRIES.

Ironstone of the Coal Measures—Description—Analyses—Production of Ironstone—Yield of Measures and Cost of Working—Pig Iron Manufacture—Early History—Darby's successful application of Coke in the blast furnace at Coalbrook Dale Works—Production of Pig Iron—Malleable Iron Works—Introduction of Rolling Mills at Coalbrook Dale—Coal consumed in Malleable Iron Works—Coal and Iron Ore used in Pig Iron Manufacture—Districts supplying Iron Ore.

Shropshire Ironstone Measures.—The upper part of the strata of this coal-field, it appears, is remarkably wanting in workable seams of coal and ironstone. The first ironstone reached in depth is the "Top" or "Chance Pennystone," occurring with much irregularity, but possessing a strong, general resemblance to the Main Pennystone, which lies about 200 feet deeper.* The table of strata shows the order of occurrence, in the neighbourhood of Donnington Wood, of the coal and ironstone seams :—

SUCCESSION OF STRATA.

STRATA.	Ft.	In.
Chance Pennystone.		
Fungous Coal	3	0
Blackstone.		
Brick Measure.		
Ballstone.		
Top Coal	5	6
Three-quarter Coal	2	0
Double Coal	5	10
Yellow Stone.		
Yard Coal	3	0
Blue Flats.		
White Flats.		
Main Pennystone.		
Sulphur Coal	7	0
Clunch Coal	3	0
Two-feet Coal	2	0
Clod Coal	2	4
Little Flint Coal	2	0
Crawstone, Madeley Wood.		
Black Flats (position not given).		

* "Iron Ores of Great Britain," Part IV., p. 241.

One of the most interesting features in the Shropshire ironstone measures is the great variety of fossil remains preserved in the interior of the nodules, exceeding in this respect those of most other districts. The following are the principal ironstone measures, in descending order, with the yield of ironstone per acre.

The Blackstone measure, an ironstone of dull lustre and irregular fracture, but having smooth, shining, and very black surfaces above and below the nodules, is highly valued in the district as one of the materials for making the "best best" cold blast iron; and the measure yields an average of 1,500 tons to the acre. The next measure, the "Brick," is one of secondary importance, existing in the form of flat cakes of a rich brown, with their surfaces very smooth, and of a chocolate colour. Planes of cleavage run very regularly through them, dividing them into brick-like masses, very like the White Flats of South Staffordshire, while a lower measure, the "*Ballstone,*" possesses a brownish-grey colour, and when broken gives a conchoidal fracture; like the Blackstone, it is extensively used in the make of the best cold blast iron.

The "Yellowstone" measure occurs below the Ballstone in lumpy, irregular nodules, with white powdery spots, yielding, when well developed, 1,200 tons of ironstone to each acre, and is used alike for both hot and cold blast iron.

The Blue Flats measure is irregular in its occurrence, the nodules are of a brown-grey colour, and exist interstratified with an indurated clay, yielding 1,600 tons of ironstone to the acre, obtained twenty years ago at a cost of 16*s*. per ton, whilst the cost of getting, at the same period, did not exceed from 8*s*. to 11*s*. per ton.

The White Flats measure.—The ironstone nodules of this measure is of a brownish-grey colour; this measure is rich in fossils, of shells, teeth, spines, crustaceans, and plants. The measure yields about 1,500 tons per acre, but does not command so high a price as those already mentioned.

The Pennystone measure is a remarkable series of nodules, yielding, where well developed, from 2,200 to 2,600 tons per acre. It is found, however, to thin out in its passage to the southern part of the coal-field, but is no longer wrought to any considerable extent. The Pennystone nodules are generally small,

brown, and with an irregular fracture, frequently containing calc spar in thin films filling cracks of contraction, as well as a white powder, which is sometimes sulphate of baryta, at others hydrous silicate of alumina. The lowest measure in the series is the *Crawstone* ironstone, and was formerly worked in the southern part of the coal-field. It was said to make an unusually strong iron, and in appearance has a singular brownish look, rough-grained nodules occurring embedded in a finely-granular sandstone, and is no longer accounted an ore of importance. Mr. W. W. Smyth, referring to these ironstones, remarks:—"The extensive piles in which the ironstone is stacked at the surface, in order to allow it by weathering to be easily freed from shale, allow of an easy inspection of large quantities of it; and perhaps nothing is more striking than the evidence that when in a soft state it has been pierced by burrowing worms, which have left heaps of excretions at the doors of their dwellings. The surface, indeed, of some of the flat nodules, diversified by those little mounds, and by tracks and small markings of many kinds, reminds one strongly of the muddy or silty flats on some of our own shores. The tubular cavities are now filled, sometimes with earthy matter and sometimes with zinc blende, a metallic mineral which in a brilliantly crystalline state often accompanies the vegetable remains."

Analyses of the Ironstone.—The ironstones of Shropshire have been very fully examined and described in the "Memoirs of the Geological Survey of Great Britain," Part IV., in which will be found a description of the coal-field,* followed by a series of analyses made in the Royal School of Mines in Dr. Percy's laboratory, and from which many of the above facts have been taken; the analyses having been made by Mr. John Spiller.

The Black Flats is thus described:—Clay ironstone, easily scratched by a steel point; colour, dark grey; fracture, subconchoidal; structure, minutely crystalline. The specimen contains a small quantity of white clay, distributed in the cavities of contraction.

The Blue Flats of Donnington Wood, and the White Flats of the same locality, are somewhat similar in character, the former containing veins of clay irregularly disposed, and the latter permeated in some parts by veins of shale. The results of examination appear in the annexed table:—

* "Iron Ores of Great Britain," Part IV., pp. 242, 245, 246.

RESULTS TABULATED.

Constituents.	Black Flats.	Blue Flats.	White Flats.
Protoxide of iron	48·28	46·30	44·33
Protoxide of manganese	0·82	0·82	1·00
Peroxide of iron			1·06
Alumina	0·67	0·48	0·92
Lime	2·26	2·30	2·86
Magnesia	1·83	2·01	1·97
Carbonic acid	32·98	31·68	30·92
Phosphoric acid	0·26	0·50	0·70
Sulphuric acid	0·10	0·11	0·06
Bisulphide of iron	0·19	0·08	0·01
Water hygroscopic	0·24	0·28	0.35
Water combined	0·62	0·81	0·95
Organic matter	0·62	0·62	0·38
Ignited insoluble residue	11·19	13·24	14·35
	100·06	99·23	99·86
IGNITED INSOLUBLE RESIDUE.			
Silica	7·36	8·23	9·90
Alumina	3·50	3·78	3·60
Peroxide of iron	0·53	0·69	0·56
Lime	0·08	trace	0·12
Magnesia	trace	0·07	trace
Potash	0·10	0·33	0·24
	11·57	13·10	14·42
Metallic iron	37·92	36·49	35·61

It is observed that none of the metals, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, were detected in 820 grains of the Black Flats ore, while a minute trace of a reddish metal, probably copper, though too small to identify, was detected in 480 grains of the White Flats ore.

The Pennystone of Donnington Wood is thus described:—"Nodular clay ironstone, easily scratched by a steel point; colour, pale brownish-grey; fracture, sub-conchoidal; structure, compact. The nodule has veins of contraction, filled with white crystals of sulphate of baryta, and a white pulverulent form of the same substance; side by side appear analyses of the same measure at Madeley Court, and of the Crawstone, at Madeley Wood."

RESULTS TABULATED.

Constituents.	Pennystone. Donnington Wood.	Pennystone. Madeley Court.	Crawstone.
Protoxide of iron	45·08	44·19	51·45
Peroxide of iron	0·55	...	...
Protoxide of manganese	1·69	0·99	0·54
Alumina	0·43	0·41	0·43
Lime	2·95	1·63	2·13
Magnesia	4·11	3·40	0·42
Carbonic acid	34·04	32·02	33·31
Phosphoric acid	0·46	0·29	0·23
Silica soluble in hydrochloric acid	0·57	0·37	...
Sulphuric acid	trace	0·06	...
Bisulphide of iron	0·48	0·43	0·02
Water hygroscopic	0·30	0·45	0·19
Water combined	0·72	1·31	0·54
Organic matter	0·23	0·42	0·67
Ignited insoluble residue	8·32	13·50	9·60
	99·93	99·47	99·53
IGNITED INSOLUBLE RESIDUE.			
Silica	5·66	7·75	6·83
Alumina	1·96	4·64	2·42
Peroxide of iron	0·26	0·55	0·43
Lime	0·16	0·14	trace
Magnesia	0·09	0·08	trace
Potash	trace	0·33	0·16
	8·13	13·49	9·84
Metallic iron	35·63	34·75	40·27

A minute trace of a white malleable metal, too small in quantity to identify, was found in 300 grains of the ore in the second Pennystone; and a trace of lead was found present in the Crawstone ore in the form of galena.

Of other argillaceous ironstones raised in Shropshire,* the following analyses, by Mr. Edward Riley, of the "Light Clod," and "Dark Clod," obtained at Billingsley Colliery, at Bridgnorth, will show the general character of the ironstone raised in the Forest of Wyre. The smelting of these ironstones, it has been stated, was formerly an industry in this neighbourhood previous to the introduction of railways, and it is said that the iron produced was of very good quality:—

* "Colliery Guardian," 28th November, 1879, p. 858.

RESULTS TABULATED.

Constituents.	Light Clod.	Dark Clod.
Silica	9·99	9·87
Carbonate of iron . . .	73·82	74·72
Alumina	06·02	6·20
Carbonate of manganese . .	1·13	1·16
,, of lime . . .	1·16	3·25
,, of magnesia . .	2·21	2·15
Sulphate of Baryta . . .	3·25	trace
Phosphoric acid	0·21	0·30
Combined water . . .	1·00	1·66
Moisture	0·66	0·72
Sulphur		0·03
Sulphate of lime	trace	trace
Small quantity of potash and organic matter . .		
	99·44	100·06
Loss by calcination . . .	36·20	28·64
Iron in calcined ore . . .	48·33	50·60
Metallic iron	35·66	36·01

Production of Ironstone.—The great bulk of the ironstone employed in the Shropshire furnaces is obtained from the coal measures of the coal-field; these, in the year 1855, were chiefly obtained from Donnington Wood and its vicinity, and from the neighbourhood of Madeley Wood, Madeley Court, &c., and amounted to 865,000 tons. In subsequent years the production of ironstone appears as follows:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1857	325,000	1869	318,483
1858	150,500	1870	337,627
1859	197,589	1871	415,972
1860	165,500	1872	408,425
1861	223,400	1873	430,725
1862	225,400	1874	303,959
1863	247,200	1875	240,568
1864	454,000	1876	239,183
1865	273,810	1877	270,733
1866	285,907	1878	321,328
1867	250,000	1879	300,391
1868	278,541	1880	226,721

The value of the ironstone delivered at the pit's bank in the year 1857, was about 5*s.* per ton on the average; in the year 1866, according to a writer in the *Colliery Guardian*, the

average cost of extracting in the Blue Flat ironstone varied, according to circumstances, from 7*s.* to 10*s.* per ton; during the same year the White Flats ironstone cost from 9*s.* to 11*s.* per ton; and the Pennystone, from 6*s.* to 9*s.* per ton. During the years from 1872 to 1876, the average price at the pit's bank varied from 10*s.* to 12*s.*, while during the past few years the average price may be taken at 10*s.* per ton. The following details of individual districts show the production in the years named :—

Districts.	1875.	1874.	1873.
	Tons.	Tons.	Tons.
Haycop	...	620	...
Ketley	7,673	9,322	9,014
Lilleshall	92,160	87,558	102,530
Madeley Court . . .	17,752	18,335	21,414
Madeley Wood . .	...	29,902	...
Quinta	...	20	...
Sandback	...	960	...
Wombridge . . .	10,556	7,242	8,234
Dawley	...	...	35,679
Coalbrookdale . . .	...	...	23,026
Old Park	...	...	10,828
Pack Moor . . .	9,000	...	...
Coppice, &c. . . .	120	...	...
Calcotts, &c. . . .	3,307	...	...
Sundry mines . .	100,000	150,000	220,000
Total . . .	240,568	303,959	430,725

Yield of Ironstone and Cost of Production.—The principal ironstone measures worked in Shropshire in 1836, according to Thomas Smith,* were as follows, showing the thickness and cost per ton of working, and the yield of ironstone per square yard :—

Ironstone Measures.	Thickness.		Yield per Yard.		Cost of Getting per Ton.		
	Yds.	Ft.	Tons.	Cwts.	£	*s.*	*d.*
Pennystone	2	0	0	4	0	6	3
Black ironstone . .	1	1	0	8	0	2	7
Brick measure . .	5	1	0	6	0	3	7
Ball stone	3	0	0	5	0	4	4
Yellow ironstone . .	3	0	0	5	0	2	0
Blue Flats . . .	2	0	0	6	0	4	2
White Flats . . .	2	0	0	4	0	6	7
Penny ironstone . .	8	0	1	4	0	5	0
Total. . .	26	2	3	2	1	14	6

* "Miner's Guide," 1836, p. 128.

The average yield per square yard of the eight measures giving 62 cwts.; the cost of getting each ton of ironstone being 8*s*. 1½*d*., this including dead work, 2*s*. 6*d*., and royalty, 1*s*. per ton. The total produce per acre of the measures giving 13,794 tons of ironstone; the royalty, 1*s*. per ton; and per acre, £689 14*s*.; the average getting of each man daily amounting to 24 cwts. 3 qrs.; and in the week of five days, 6 tons 3 cwts. 2 qrs.

Pig Iron Manufacture.—The early history of this industry is intimately associated with Shropshire and especially with the Coalbrookdale Ironworks. When, in the beginning of the last century, the exhaustion of our forests and woodlands was imminent, occasioned by the demand for the necessary charcoal fuel, attention was directed to the useful application of coal in the blast furnace. The difficulties, however, were considerable, and it was not until Mr. Abraham Darby, between the years 1730 and 1735, at the Coalbrookdale Works, successfully solved the problem, that the use of coal, previously coked, came into use in the reduction of the ores of iron in the blast furnace.

The new era opened out by Darby's success in the application of coke renders this a fitting place to give the following account of his early attempts:—*

"Young Abraham Darby entered upon the management of the Coalbrookdale Ironworks about 1730. As the supply of charcoal was fast failing, Abraham Darby attempted to smelt with a mixture of raw coal and charcoal, but did not succeed. Between 1730 and 1735 he determined to treat pit coal as his charcoal burners treated wood. He built a fire-proof hearth in the open air, piled upon it a circular mound of coal, and covered it with clay and cinders, leaving access to just sufficient air to maintain slow combustion. Having thus made a good stock of coke, he proceeded to experiment upon it as a substitute for charcoal. He himself watched the filling of his furnace during six days and nights, having no regular sleep, and taking his meals at the furnace top. On the sixth evening, after many disappointments, the experiment succeeded, and the iron ran out well. He then fell asleep in the bridge-house at the top of his old-fashioned furnace so soundly that his men could not wake him, and carried him to his house a quarter of a mile distant."

* Percy's Metallurgy, "Iron and Steel," p. 888.

It may also be mentioned that it was at the above-named works that Mr. Abraham Darby's father had previously introduced the art of casting iron, and that at a later period the first iron bridge constructed in this country was successfully carried out, and is that which at the present time spans the river Severn at the thriving town of Ironbridge.

Darby, in the year 1735, having succeeded in making pig iron with coke, experienced a new difficulty, that of securing blast of sufficient pressure to ensure the complete utilisation and combustion of the hard dense coke in the furnace, and it was not until a quarter of a century later that his difficulty was overcome by the introduction of powerful blowing machinery, in which Smeaton led the way, followed by Watt and others. In the year 1740, when the total production of pig iron in England and Wales was but 17,350 tons, the yield of 59 furnaces, that of the six furnaces then in operation in Shropshire was 2,100 tons, 12 per cent. of all made; the average yield of each furnace being 350 tons. In the year 1754 the ironworks at Horsehay were established by Mr. Abraham Darby, of Coalbrookdale, already referred to, and two years later the first furnace was blown in. It is recorded that from 20 to 22 tons of coke pig iron were made weekly, and such was its superior quality that it met with a ready sale. Advancing to the year 1788, when the total production of pig iron was 61,300 tons, of which 13,100 tons was charcoal pig, and 48,200 tons coke pig, the make of the Shropshire furnaces was as follows:—

Description.	Furnaces.	Pig Iron.
	Nos.	Tons.
Coke iron	21	23,100
Charcoal iron	3	1,800
Total . . .	24	24,900

The fact of the Shropshire furnaces at this period contributing upwards of 40 per cent. of the iron made in England and Wales shows the importance of the district as a seat of iron manufacture.

Towards the close of the last century additional light was thrown on the progress of the iron trade of the country by the

inquiries of a Committee of the House of Commons, presided over by William Manning, Esq., M.P. From the investigations of this committee, and the authority of Dr. H. G. Macnab, who represented the iron trade, we learn that in the year 1796 the production of pig iron in Great Britain was 125,079 tons, of which Shropshire contributed 32,969 tons, nearly 25 per cent. of all made at this period. In the annexed table appear the works in operation in 1796 in Shropshire, the number of furnaces, and their production :—

Works.	Number of Furnaces.	Pig Iron Made.	Average per Furnace.
		Tons.	Tons.
Benthall . . .	1	1,334	1,334
Broseley	1	1,076	1,076
Coalbrookdale . .	3	2,660	886
Donnington Wood . .	2	3,323	1,608
Horsehay . . .	1	1,458	1,458
Jackfield	2	1,820	910
Ketley	3	5,069	1,689
Light Moor . . .	3	3,499	1,166
Madeley Wood . .	1	1,856	1,856
Old Park	3	5,952	1,984
Snedshill . . .	2	3,367	1,683
Willey	1	1,555	1,555
Total. . .	23	32,969	1,433

Thus while in the year 1740 the average make per furnace was 294 tons, it increased in the year 1796 to 1,433 tons, from which fact it will be seen that the furnaces will have been reconstructed and their capacity greatly increased. In 1796, when the production of the Shropshire furnaces was 32,969 tons, the only other iron making districts in Great Britain exceeding this was South Wales, producing 34,101 tons; Scotland following with 15,186 tons; South Staffordshire with 13,210 tons; the West Riding of Yorkshire with 10,398 tons; Derbyshire with 9,656 tons; North Staffordshire with 1,959 tons; and the charcoal furnaces of Sussex with 173 tons. The beginning of the present century was marked by the establishment of several new works, an increase in number and capacity of the furnaces and production of pig iron. Thus in the year 1806 we have the subjoined details of works, furnaces built, and in blast, and make of pig iron in Shropshire, showing an increase of 21,997 tons in a period of ten years, equal to 66 per cent. :—

Works.	Furnaces.		Pig Iron Made.
	Built.	In Blast.	
	Nos.	Nos.	Tons.
Barnets Leasow	2	1	574
Benthall	1	1	1,294
Billingsley	2	0	...
Broseley	1	1	1,450
Calcott	5	1	2,269
Clee Hill	1	1	303
Coalbrookdale	2	2	2,962
Cornbrook	1	1	292
Donnington Wood	3	2	3,400
Horsehay	2	2	3,834
Light Moor	3	3	5,601
Ketley	4	2	7,510
Madeley Wood	2	2	2,951
New Hadley	2	2	3,612
Old Park	4	4	8,359
Queenswood	1	1	2,605
Snedshill	3	2	3,950
Willey	1	0	...
Wrockwardine	2	2	4,000
Total	42	30	54,966

The total production of pig iron in Great Britain, in the same year, was 243,851 tons, distributed as follows:—

Districts.	Furnaces.			Pig Iron Made.
	Built.	In Blast.	Out.	
	Nos.	Nos.	Nos.	Tons.
England	140	105	35	149,163
Wales, North	4	3	1	2,981
,, South	45	35	10	68,867
Scotland	27	18	9	22,840
Total	216	161	55	243,851

Shropshire at this period contributed upwards of 20 per cent. of the iron produced in the kingdom, while the average make of her blast furnaces had increased from 1,433 tons in the year 1796 to 1,832 tons in the year 1806.

Advancing to the years 1831—32, when an inquiry was conducted for the Government by Mr. F. Finch, it was ascertained by that gentleman that in the years 1823 and 1830 the furnaces in operation, and the make of pig iron in Shropshire, were as follows:—

Works.	1823.		1830.	
	Number of Furnaces.	Pig Iron Made.	Number of Furnaces.	Pig Iron Made.
		Tons.		Tons.
Broseley . . .	2	...	2	270
Barnets Leasow . .	2	2,755	2	1,316
Benthall . . .	1	...	1	...
Calcotts	2	1,833	2	...
Coalbrookdale . .	2		2	
Dawley Castle . . .	2	4,925	2	4,312
Donnington . . .	3*	8,074	5	15,110
Horsehay	3	4,854	3	6,833
Hadley	2	2,080	2	...
Ketley	3	4,984	3	5,763
Light Moor . . .	3	6,052	3	6,194
Madeley Wood . . .	3	2,475	3	3,471
Old Park	4	6,900	4	15,300
Snedshill	2	2,786	2	317
Wombridge . . .	2	5,084	3	7,134
Wrockwardine . . .	2	5,121	2	...
Stirchley . . .	...	...	4†	...
Lawley	...	...	1	3,073
Langley . . .	...	...	2	4,325
Total . . .	38	57,923	48	73,418

The aggregate production of pig iron in the year 1823, in the works of Great Britain, was 454,866 tons, increased in the year 1830 to 678,417 tons, equal to an increase of 50 per cent., while in the works of Shropshire the increase between the same years was 15,495 tons, or 26 per cent.

It was between the above-named years (in 1828) that the Hot Blast, the invention of Mr. James B. Neilson, was introduced; and returns in subsequent years show the important influence exercised in increased production, more especially in Scotland. Later the system was adopted in England and Wales, though but partially in some districts, as for example the West Riding of Yorkshire, North Staffordshire, South Wales, and in this district, where some of the works still employ cold blast in the furnace, producing iron of a superior quality, which is in great request.

The next return is for the year 1839, on the authority of

* Two furnaces were built at Donnington in 1828, in the place of the two at Wrockwardine which were blown out.

† The quantity made in 1830 is included in the Old Park return.

Mr. Robert Mashet,* who states that of the 34 furnaces built in Shropshire at that date 29 were in blast, and produced 80,940 tons, giving an average yield to each furnace of 2,791 tons. Again, in 1840 we find, from Mr. William Jessop's inquiries, that of the total furnaces built 24 were active, and produced 82,750 tons of pig iron, consuming in its manufacture 409,000 tons of coal, the average yield per furnace being 3,448 tons of iron, with an average of nearly 5 tons of coal to each ton of iron made.

The returns a few years later show a falling off not only in Shropshire, but in nearly all the iron-making districts of Great Britain—Northumberland and North Staffordshire excepted. Thus in 1848 the production had fallen to 1,215,350 tons, compared with 1,396,400 tons in the year 1840; the make of the Shropshire furnaces being respectively, in each of the same years, 76,200 tons and 82,750 tons. This falling off was due to depression of trade, which was general throughout the industries of the country, and continued from 1840 to 1845, when a reaction set in, due to the extension of the railway system, leading to increased demand for iron of all kinds and more remunerative prices.

The results of these changes appear in the returns for the year 1847, when of the 623 furnaces built in Great Britain 433 were in operation, and produced 1,999,608 tons of pig iron, of which the 28 furnaces in blast in Shropshire, out of a total of 34 built, yielded 88,400 tons, or an average of 3,157 tons per furnace.

The iron industries of the country since 1847 have bounded forward at a rapid pace, to meet the many requirements to which iron is now so universally applied; not only in the structural arrangements of our public buildings, railway, and naval engineering works, but also the many other works of national importance to which it is now so generally adapted.

In the year 1852 Mr. Braithwaite Poole, in his "Statistics of Commerce," gives the production of pig iron in Shropshire as 120,000 tons, giving an average of 4,444 tons for each of the 27 furnaces in blast, compared with 3,157 tons per furnace in the year 1847. In 1852 the same authority gives the total production of pig iron in Great Britain as 2,701,000 tons, the make of 497 furnaces then in operation, out of a total of 655 furnaces built.

* "Papers on Iron and Steel," p. 421.

Advancing to the year 1854, of the 34 furnaces erected in Shropshire 28 were in blast, the production of pig iron amounting to 124,800 tons, being an average of 4,457 tons per furnace. In the annexed table will be found the number of furnaces built, in blast, and the make of pig iron in Shropshire in each year since 1855 :—

Year.	Furnaces. Built.	Furnaces. In Blast.	Pig Iron Made.	Year.	Furnaces. Built.	Furnaces. In Blast.	Pig Iron Made.
	Nos.	Nos.	Tons.		Nos.	Nos.	Tons.
1855	34	26	121,680	1868	29	24	145,159
1856	35	27	109,722	1869	29	23	197,443
1857	31	26	117,141	1870	29	22	112,300
1858	32	25	101,016	1871	25	19	129,467
1859	37	30	149,480	1872	29	22	133,046
1860	32	26	145,200	1873	29	21	135,149
1861	31	22½	140,791	1874	28	20	126,055
1862	31	23	125,981	1875	26	20	120,996
1863	31	22	135,557	1876	25	16	106,711
1864	30	22¾	130,666	1877	23	14	102,180
1865	29	23	117,343	1878	28	11	80,965
1866	29	23	121,161	1879	23	7	60,790
1867	29	22	123,604	1880	24	12	88,338

During the past few years Shropshire shows a decrease in this branch of industry. Of the ironworks it may be remarked that the Lilleshall and Haybridge companies' works, and those at Madeley Court, are the most recently established. These works are of considerable magnitude, the first named, at Prior's Lee, having four furnaces, and the Lodge Wood works five furnaces, making cold blast pig iron. These works are situated near Shiffnall, and possess, in addition to the furnaces, extensive foundries and engineering establishments, where locomotives for colliery purposes are made on a large scale. The works of the Haybridge Company are also situated near Shiffnall, while those of Madeley Court are situated near Ironbridge.

The year of greatest production appears to have been in 1869, when of the 29 furnaces in the Shropshire works, the 23 in blast produced 197,443 tons, compared with 88,338 tons in 1880, when of the 24 furnaces in the district but 12 were in operation.

The following table shows the names of the works, firms, and furnaces built and in operation during the year 1880 in Shropshire :—

Works.	Owners.	Furnaces.	
		Built.	In Blast.
		Nos.	Nos.
Hinkshay, Shiffnall . .	Haybridge Iron Co., Lim.	2	0
Light Moor and Dawley Castle	Coalbrookdale Iron Co., Limited . . .	4	1
*Ketley, Wellington . .	Ketley Co.		
Lodge Wood, Shiffnall . .	Lilleshall Co.	5	3
Prior's Lee, Shiffnall . .	,, ...	4	3
Madeley Wood, Ironbridge .	Madeley Wood Co. . .	3	3
Madeley Court . . .	William Orme Foster .	3	2†
Old Park	Edward Cheney . . .	3	0
	Total . . .	24	12

Malleable Ironworks, Mills, and Forges. — The earliest works established in Shropshire were those of the Coalbrookdale Iron Company, projected about the year 1753. They are situated at Horshay, near Wellington, and comprise forges and rolling mills. When, in 1783 Mr. Henry Cort introduced his system of rolling iron, the works were considerably enlarged and rolling mills erected. The site of the Dale was originally selected for the erection of an iron foundry, on account of the facilities it afforded for water power by the rapid descent of its brook into the river Severn. Water power has, however, long since been almost entirely superseded by steam in these old-established works, which are said to have been in the family of the present proprietors for nearly 180 years, during which period they have been greatly extended. The locality is described as a picturesque and once sequestered valley, now busy with the life and labour of those employed in the foundries and workshops of the company, the latter buildings occupying the larger portion of the bottom of the Dale, while the slopes of the hills are occupied by coppice and field, and by the houses and gardens of the workmen employed. A local authority in 1856 estimated the annual production of finished iron at these works at 15,000 tons, consisting of bars of all sizes and sections.

It was at Coalbrookdale, it appears, that Cort first systematically conducted the processes of puddling and of drawing out

* Works recently dismantled.

† One furnace a part of the year only.

the puddled balls through grooved rolls. Dr. Percy, in referring to Cort's claim, says: "With respect to the invention of grooved rolls, it has been maintained that Cort's claim is invalidated by the old patent granted to John Payne in 1728," and follows with an extract from the specification relating to grooved rolls: "The improvement in the manufacture of iron consists in putting certain ingredients into fusion with pig or sow-iron; videlecit, the ashes of wood and other vegetables, all kinds of glass and sandever, common salt, argile, kelp, and potash, slegg or cinders from iron furnaces and forges; proportionable parts of the said ingredients being put into fusion, or melted with pig, sow, or other brittle iron, which will make the like change as charcoal does in the fire called the finery in common forges, and will render the same into a state of malleability, as to bear the stroke of the hammer, to draw it into barrs or other forms at the pleasure of the workman, and those or other barrs being treated in the same melted ingredients in a long hott arch or cavern, as hereafter is described; and those or other barrs are to pass between two large metal rollers (which have proper notches or furrows upon their surfass), by the force of my engine hereafter described, or other power, into such shapes and forms as shall be required." The engine consisted of a large vane wheel, hung in a frame in the side of a building, the pressure of the in-current of air being directed upon the extremities of the vanes.

Dr. Percy further adds, "That something very like grooved rolls is here described cannot be denied; but there is not, so far as I am aware, the slightest evidence to show that Payne ever attempted to carry out his scheme into practice. Indeed, the proposal to work the notched rolls by such a wheel as is specified, pretty clearly shows that Payne was not aware of the power needed to drive any machinery equivalent to puddle rolls."

Following the establishing of the Coalbrookdale works, about the year 1783, those at Ketley are amongst the oldest in the county, indeed, it might be said in the kingdom, and it was here the first iron railway was laid down towards the close of the last century; the Ketley Works are well known in the commercial world for the high character of their manufacture, bars, hoops,

* Metallurgy, "Iron and Steel," p. 635.

and wire rods. Recently, however, these old-established works were closed, and in 1879 dismantled.

The Snedshill and the Coalbrookdale Iron Companies are generally regarded as the largest manufacturers of malleable iron in Shropshire, possessing considerable resources for manufacturing and producing plates, wire rods, and hoops of the best varieties. The first named works were originally founded by Messrs. Samuel Horton and William Simms, and at the present time exist under the management of the Snedshill Bar-iron Company. The annexed list, the latest published (1880), shows the works existing, their owners, together with the number of mills and forges in operation:—

Works.	Owners.	Situation.	No. of Puddling Furnaces.	No. of Rolling Mills.
Castle, Hadley .	Messrs. Nettlefolds . . .	Wellington	27	3
Horsehay . .	Coalbrookdale Iron Co. . . .	"	36	5
Stirchley . .	Haybridge Iron Co. . . .	"	14	2
Eagle, Hollingswood .	The Eagle Iron Works Co., Lim.	"	18	3
Trench, Hadley .	The Shropshire Iron Co., Lim. .	"	32	3
Shropshire . .	" " .	"		
Wombridge . .	Wombridge Iron Co., Limited .	"	10	3
Haybridge . .	Haybridge Iron Works Co., Lim.	"	10	1
Old Park* . .	Old Park Iron Co. . . .	Shiffnal	..	..
Snedshill . .	Snedshill Iron Co.	"	36	4
	Total of County . .	. .	183	24

The pig iron employed in these works is chiefly furnished by the blast furnaces of the district, those of Snedshill being supplied by the Lilleshall Company's furnaces in Shropshire, who also supply the Shelton Bar-iron Company's works, situated at Hanley, North Staffordshire; while the Coalbrookdale Company's works at Horsehay are supplied from their own Light Moor and Dawley Castle furnaces.

The Haybridge Iron Company, a few years since, added a new feature to the manufacturing industries of the county by the introduction of suitable machinery for the manufacture of nails, an industry previously carried on at these works by the aid of hand labour.

The coal employed in the malleable ironworks of Shropshire in the years 1872 and 1873 amounted to 160,000 tons in each year, giving an average consumption of coal to each puddling

* Works standing.

furnace of 900 tons, and, taking the quantity of coal necessary to convert the pig into finished iron of various forms at 50 cwt., there would appear to have been about 64,000 tons of finished iron produced in the works of Shropshire in each of the above years. In recent years the consumption of coal in these works has been approximately ascertained as follows:—

Year.	Coal.	Year.	Coal.
	Tons.		Tons.
1872	160,000	1876	138,000
1873	160,000	1877	134,500
1874	154,000	1878	139,780
1875	146,000	1879	141,329

The quantity consumed in these works in 1880 amounted to 158,992 tons.

Coal and Iron-ore used in Manufacture.—Mr. David Mushet, in his papers on "Iron and Steel," states that four tons of coke was the quantity of fuel employed in the year 1810 for each ton of pig iron made in Great Britain. In Shropshire it was ascertained, about the year 1840, by Mr. William Jessop, of the Butterley Ironworks, that the quantity of pig iron made was 82,750 tons, consuming in its manufacture 409,000 tons of coal, or nearly five tons of coal to each ton of pig iron made. Mr. William Jessop further ascertained that the total quantity of pig iron made in Great Britain the same year amounted to 1,396,400 tons, consuming 4,877,000 tons of coal, or an average of 3½ tons of coal to each ton of pig iron manufactured.

The inquiry instituted by the Royal Coal Commission shows that in the year 1869 the quantity of coal employed in making a ton of pig iron in Great Britain did not exceed three tons, and subsequent inquiries, instituted by the Mining Record Office, show that in Shropshire, in the years 1871 and 1872, it amounted to the same average quantity, while taking the iron-making districts of the kingdom in the same year the average did not exceed 51 cwts. of coal to each ton of pig iron made.

In the year 1872 and following years, the production of pig iron in Shropshire, together with the quantities of coal and ore used in its manufacture, will be found in the annexed statement:—

Year.	Pig Iron.	Coal Used.	Ore Used.	Average per Ton.	
				Coal.	Ore.
	Tons.	Tons.	Tons.	Cwts.	Cwts.
1872	133,046	398,197	385,000	60	57
1873	135,149	407,876	390,000	60	58
1874	126,055	394,094	364,500	62	57
1875	120,996	370,000	350,000	61	57
1876	106,711	334,738	307,500	63	57
1877	102,180	276,241	293,000	54	57½
1878	80,965	222,876	231,060	55	57
1879	60,790	156,507	153,198	51	50½
1880	88,338	249,254	218,650	56	49½

The Shropshire ore yields an average of 36 per cent. of metallic iron, other ores used to a limited extent giving a higher yield; North Staffordshire ores, 36½ per cent.; Northampton ores, 40 per cent.; while ores used in small quantities, chiefly hematite, yield probably not less than 50 per cent. of metallic iron. The ores used in Shropshire in each of the following years were obtained from the districts named:—

Districts.	1873.	1875.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.
Shropshire . . .	306,500	268,000	136,839	218,650
North Staffordshire . .	6,500	7,200	6,380	
Northamptonshire. .	50,000	40,300	3,890	
Other districts . . .	27,000	34,500	7,089	
Total . .	390,000	350,000	153,198	218,650

It has not been found possible to determine the respective quantities of ore furnished by various districts in 1880 as in previous years; it is, however, known that of the 218,650 tons of ore reduced in the blast furnaces of Shropshire, the approximate quantity of ironstone supplied by the district amounted to not less than 200,000 tons.

CHAPTER X.

NORTH STAFFORDSHIRE IRON INDUSTRIES.

Description and Analyses of the Ironstones of the Coal Measures—Churnet Valley Ore and Analysis—Production and Distribution by Canal and Railway—Pig Iron Manufacture—Early History—Apedale and Silverdale Iron Works—Furnaces in Blast and Production of Pig Iron—Malleable Iron Works and Coal used—List of Works in 1880—Coal and Iron Ore used in Manufacture—Districts furnishing Ore.

Description and Analyses of the Ores.—The ironstones of North Staffordshire are very fully described in the "Iron Ores of Great Britain," Part IV., by Prof. W. W. Smyth, F.R.S., and complete analyses are published by Dr. Percy, F.R.S., made in his laboratory in the Royal School of Mines, in the same Memoir. The more important are the following:—

The "Red Shag," Shelton Colliery, Hanley and Apedale, Newcastle.—Clay-iron ore; colour, dark brown to black; structure, compact, with reddish brown flattened impressions of fossil shells.

"Gutter Mine," Shelton Colliery, Hanley.—This ore is "composed of alternate layers of clay, ironstone, coaly matter and fossil shells; the clay-ironstone predominating towards the middle of the specimen." It readily cleaves in the direction of the plane of stratification, the shells thus displayed bearing the evidence of compression in a direction perpendicular to the plane of cleavage. A small quantity of zinc blende was found in the ore.

"Red Mine," Apedale, is a clay-iron ore, consisting of thin layers; colour, various shades of dark brown; structure, compact. Minute crystals of galena and zinc blende occur, sparingly diffused through the ore.

Analyses of these ores and the "Bassy Mine" appear in the annexed table. That of the "Gutter Mine" by Mr. John Spiller, the others by Mr. A. B. Dick:—

RESULTS TABULATED—ORE DRIED AT 100° C.

Constituents.	Red Shag.	Gutter Mine.	Red Mine.	Bassy Mine.
Protoxide of iron	46·53	34·22	50·73	45·53
Peroxide of iron	...	0·68	0·45	5·00
Protoxide of manganese	2·54	2·87	1·86	1·74
Alumina	0·97	0·23	0·26	0·32
Lime	2·41	11·91	2·52	2·91
Magnesia	1·39	1·44	1·26	2·13
Carbonic acid	30·77	32·52	33·89	32·12
Phosphoric acid	0·69	0·87	0·73	0·86
Sulphuric acid	0·04	0·12	0·08	0·08
Bisulphide of iron	0·34	0·35	0·30	0·37
Water	1·47	0·98	*	2·29
Organic matter	10·46	8·93	6·41	5·20
Ignited insoluble residue	2·27	4·57	0·72	1·95
Total	99·88	99·69	99·21	100·50
IGNITED INSOLUBLE RESIDUE.				
Silica	1·93	3·13	0·38	1·36
Alumina	0·25	1·12	0·32	0·42
Peroxide of iron	0·05	0·33	...	0·06
Lime	0·03	traces.	0·03	...
Potash	0·20	traces.	0·14	0·05
Magnesia	...	...	...	...
Total	2·46	4·58	0·87	1·89
Metallic iron	36·39	27·33	39·84	39·13

It is further observed, in reference to the foregoing analyses, that no metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution was detected in 750 grains of the Red Shag iron ore; while in the "Gutter Mine" distinct traces of lead and copper were detected in 760 grains of the ore. Again, in the "Red Mine" and "Bassy Mine" no metals precipitable under similar conditions were detected in 680 grains of the former and 1,180 grains of the last named ore.

The ironstone is calcined at the mine's mouth with inferior coal. Before the operation it varies in richness from 34 to 58 per cent. of protoxide of iron and afterwards runs as high as 90 per cent. of the peroxide. The following will show the general conditions of the raw and calcined ores of the "Red

* Undetermined.

Shag" and "Red Mine" ironstones already referred to and in extensive use in North Staffordshire. The following analyses are by Mr. W. H. Merritt, Associate of the Royal School of Mines:—

Constituents.	RED SHAG.		RED MINE.	
	Raw.	Calcined.	Raw.	Calcined.
Peroxide of iron	...	91·50	...	92·52
Protoxide of iron	45·30	...	50·90	...
Peroxide of manganese	...	4·12	...	2·44
Protoxide of manganese	2·23	...	1·76	...
Alumina	0·32	0·55	0·73	0·59
Silica	0·50	0·86	1·13	0·79
Lime	0·64	1·10	2·07	1·79
Magnesia	0·20	0·34	0·80	0·94
Sulphide of iron	0·32	...	1·10	...
Phosphoric Acid	0·90	1·53	0·62	0·93
Combined water	1·07	...	0·12	...
Carbon	18·60	...	8·75	...
Carbonic acid	29·92	...	33·02	...
Total	100·00	100·00	100·00	100·00
Metallic iron	35·40	64·05	39·58	64·77
Metallic manganese	1·72	2·97	1·35	1·75

The other important measures of North Staffordshire reported upon in the "Iron Ores of Great Britain," are the following:—

"**Cannel Mine,**" Apedale.—A clay ironstone; colour, dark grey; fracture, subconchoidal; structure, compact. The ore is intersected by very thin veins of carbonate of lime.

"**Pennystone,**" Shelton Colliery.—A clay ironstone; colour, brown; structure, compact. And containing crystals of zinc blende.

The "Deep Mine" and "Chalky Mine" ironstone measures, at the Folly and Shelton Collieries, are described as clay iron ores, greyish black and dark brown in colour; structure, compact. And containing minute crystals of zinc blende and pyrites, as well as hydrated silicate of alumina and carbonate of lime.

The analysis of the Cannel Mine ironstone is by Mr. John Spiller, the others by Mr. A. Dick:—

NOTE.—A general description of the foregoing ironstone measures of North Staffordshire, their thickness and order of occurrence, will be found in Part I., pp. 142, 143.

Constituents.	Cannel Mine.	Penny-stone.	Deep Mine.	Chalky Mine.
Protoxide of iron	41·80	46·35	48·33	51·07
Peroxide of iron	...	3·00	...	...
Protoxide of manganese	2·16	1·61	2·99	2·36
Alumina	0·53	0·30	0·41	0·54
Lime	5·07	1·93	1·52	1·74
Magnesia	3·03	2·24	1·19	1·10
Carbonic acid	32·40	32·46	32·76	33·63
Phosphoric acid	1·40	0·67	0·87	1·12
Sulphuric acid	trace.	trace.	trace.	trace.
Bisulphide of iron	0·04	0·15	0·19	0·17
Water hygroscopic	0·36	1·43	0·85	0·99
Water combined	0·71			
Organic matter	0·79	2·95	1·17	1·24
Ignited insoluble residue	10·81	7·29	9·28	5·18
Total	99·10	100·38	99·56	99·14
Ignited Insoluble Residue.				
Silica	7·32	5·78	6·25	3·02
Alumina	3·28	1·22	2·41	1·93
Peroxide of iron	0·20	0·11	0·21	0·12
Lime	0·04	...	...	...
Magnesia	trace.	...	...	...
Potash	0·09	0·18	0·22	0·28
Total	10·93	7·29	9·09	5·35
Metallic iron	32·64	38·29	37·83	39·88

Near the base of the coal measure series, and in the neighbourhood of Froghall, Ipstones, and Consall, the valuable Churnet Valley ore occurs; a calcareous iron ore accidentally discovered some twenty-five years ago by a Mr. Bishop, a Cornishman, while a search was being prosecuted by explorations in depth for a seam of coal.

This Churnet Valley ore exists in a very irregular seam, varying in thickness from 6 to 20 inches, and embedded in the red shales of the lower coal measures; it is really a limestone highly impregnated with hydrated peroxide of iron, and though its area is limited it has, in past years, furnished large supplies of ironstone, which have recently considerably diminished, and its ultimate exhaustion may at no distant period be expected. The Churnet Valley ore is not calcined previous to its reduction, but is employed in admixture with other ores; the large amount of lime-

stone it contains (14·61 per cent.) rendering it valuable as a flux.

The Froghall ore occurring in the neighbourhood of Cheadle is thus described by Mr. A. Dick. "Calcareous hematite; colour, brownish red; structure, compact and homogeneous; a vein of calcareous spar occurs in it." The following results tabulated show its composition:—*

RESULTS TABULATED.—ORE DRIED AT 100° C.

Peroxide of iron	52·83
Protoxide of manganese	0·81
Lime	14·61
Magnesia	5·70
Carbonic acid	18·14
Phosphoric acid	0·32
Sulphuric acid	0·28
Silica	trace.
Water	4·75
Organic matter	1·30
Ignited insoluble residue	0·04
Total	98·78
Metallic iron	36·98

By passing sulphuretted hydrogen through the hydrochloria acid solution of 450 grains of ore and reducing the precipitate before the blowpipe, a minute trace of whitish metal was obtained. It was too small in quantity to be identified.

The argillaceous ironstone of North Staffordshire is calcined on an extensive scale, by which the metallic iron is concentrated, the bulk considerably reduced, and in this state it is largely exported to South Staffordshire to supply the furnaces of that district. The siliceous and argillaceous ironstones of the district lose in weight by calcination from 30 to 36 per cent.; the yield of metallic iron in the calcined state being 65 per cent. The "Black Band," or carbonaceous ironstone, loses by calcination from 50 to 60 per cent., and even more by weight, while the metallic iron, in the calcined state, yields by analysis nearly 70 per cent. This high percentage of metallic iron is not, however, secured practically in the blast furnace in the process of smelting.

Production and Distribution of Ironstone.—In the year 1855 the ironstone raised in North Staffordshire amounted to 512,000

* "Iron Ores of Great Britain," p. 291.

tons of which 210,500 tons were sent into South Staffordshire. The argillaceous ore sent away is chiefly calcined, losing by the operation about one-third of its weight, in which form it yields, on reduction, 65 per cent. in the blast furnace. Since 1856 the yield of the mines has been as follows, distinguishing as far as possible the calcareous ores from the ores of argillaceous carbonate, the average value of which may be taken at 7*s*. per ton :—

Year.	Hydrated Oxide.	Calcareous Hæmatite.	Total.
	Tons.	Tons.	Tons.
1856	...	...	520,000
1857	349,947	300,000	649,000
1858	349,000	350,000	699,000
1859	349,000	275,000	624,000
1860	482,729	250,500	733,229
1861	349,195	150,000	499,195
1862	500,834	145,500	646,334
1863	541,059	140,750	681,809
1864	297,000	285,750	582,750
1865	550,491	275,000	825,491
1866	462,371	149,872	612,243
1867	544,509	250,000	794,509

In subsequent years the returns include raw and calcined stone not always reduced to the same equivalent, namely, raw stone; it will therefore be more convenient to follow the returns of distribution by railway and canal indicating the movement of ironstone in the district and to places beyond.

Few districts possess greater facilities for the transport of minerals than that of North Staffordshire, traversed by the Trent and Mersey Navigation and the North Staffordshire Railway.

The annexed statement gives the total quantities of iron ore, calcined and raw, carried by the above-named canal and railway in each of the years since 1861, increasing from 349,198 tons in 1861 to 481,673 tons in the year 1880. The respective quantities carried in each of those years being thus distinguished :—

How Distributed.	1861. Quantities.	1880. Quantities.
	Tons.	Tons.
Trent and Mersey Navigation . .	231,965	101,356
North Staffordshire Railway . . .	117,233	380,317
Total	349,198	481,673

Year.	Canal.	Railway.	Total.
	Tons.	Tons.	Tons.
1861	231,965	117,233	349,198
1862	292,515	208,319	500,834
1863	203,800	337,259	541,059
1864	280,648	256,061	536,709
1865	263,933	286,558	550,491
1866	283,637	328,606	612,243
1867	225,806	318,703	544,509
1868	192,657	316,406	509,063
1869	215,796	380,098	595,894
1870	207,118	438,036	645,154
1871	221,452	509,055	730,507
1872	213,246	559,958	773,204
1873	198,368	464,983	663,351
1874	153,161	368,558	521,719
1875	149,605	363,746	513,351
1876	120,606	345,647	466,253
1877	108,413	333,504	441,917
1878	92,209	308,466	400,675
1879	75,864	299,030	374,894
1880	101,356	380,317	481,673

These returns give the output of ironstone, while a reference to the following table shows the proportion of calcined to uncalcined stone, and gives the quantities used in the district. The value of the latter in the years 1872 and 1873 was 12*s*. per ton, and in the year 1880 but 10*s*. per ton:—

Distribution.	1861.	1864.	1867.	1870.	1873.	1877.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Trent and Mersey Navigation.								
Calcined Ironstone exported.	103,791	109,150	137,681	111,108	108,939	61,354	53,123	68,167
Calcined Ironstone used in District	15,435	23,874	14,618	48,663	37,421	28,725	12,547	7,802
Uncalcined Ironstone sent out of District . .	112,739	147,615	73,507	47,347	52,008	18,334	10,194	25,387
Total by Canal	231,965	280,648	225,806	207,118	198,368	108,413	75,864	101,356
North Staffordshire Railway.								
Calcined Ironstone exported.	68,884	125,715	190,430	207,098	342,072	190,655	180,898	246,043
Uncalcined Ironstone ,, .	11,438	12,853	7,156	13,167	13,646	10,281	7,276	12,014
Calcined Ironstone conveyed to local Stations . .	32,693	116,594	120,159	125,403	107,543	131,798	108,739	12,203
Uncalcined Ironstone ditto .	4,218	899	958	2,368	1,722	770	2,117	229
Total by Railway . . .	117,233	256,061	318,703	438,036	464,983	333,504	299,030	380,317
Total by Canal and Railway.	349,198	536,709	544,509	645,154	663,351	441,917	374,894	481,673

Pig Iron Manufacture.—The earliest evidence of the manufacture of pig iron in North Staffordshire is afforded by a return to Parliament in the year 1796, when it was ascertained the only works existing at that time were those at Apedale of

Messrs. G. Parker and Co., and Silverdale of Mr. R. Sneyd, the furnace at Apedale producing 2,100 tons and that at Silverdale 2,600 tons, or a total of 4,700 tons; the total production of pig iron in the furnaces of Great Britain the same year being 183,407 tons.

In the year 1806 the Apedale furnace produced 1,400 tons and the Silverdale 1,010 tons, a total of 2,410 tons. In subsequent returns for many years the production of the district is included in that of South Staffordshire. When, in the year 1839, the make of the seven furnaces then in operation in North Staffordshire was ascertained, it amounted to 18,200 tons, and in 1840 to 20,500 tons. Between 1839 and 1848 several works were established, and when in the last-named year a Parliamentary return appeared, the works and firms, with the furnaces built and in blast, were as follows:—

Works.	Owners.	Furnaces.		Pig Iron.
		Built.	In Blast.	Tons.
Apedale	E. E. Heathcote	4	4	18,720
Etruria	Earl Granville	3	2	7,280
Kidsgrove	Thomas Kinnersley	3	3	13,520
Lane End	W. H. Sparrow	3	2	8,320
Madeley	Thomas Firmstone	2	1	4,160
Silverdale	R. Sneyd	2	2	7,280
Tunstall	Williamson Brothers	2	2	6,240
	Total	19	16	65,520

Comparing the average production per furnace in the year 1848 with previous years we have the annexed results. In 1848 the average was 4,095 tons; in 1840 but 2,600 tons; while in 1796 the average did not exceed 1,566 tons.

The next return available is for the year 1852, when the number of furnaces in North Staffordshire increased to 21, of which 17 were in blast, producing 90,000 tons of pig iron, giving an average make per furnace of 5,296 tons. Mr. Braithwaite Poole, in his "Statistics of Commerce" for the same year, gives the total production of pig iron in Great Britain as 2,701,000 tons, there being 655 furnaces built at that time, of which 497 were in blast.

Mr. Merritt, in his paper on the "North Staffordshire Coal

and Iron District," * refers the average height of the blast furnaces of this district to from 50 to 70 feet, and that those using coal will not stand a greater height than the latter, to which most of the new furnaces are being raised, and as the coal causes a little coking in the hearth, a process is in some places resorted to which is seldom met with elsewhere. The furnace is found to work better if the sides and bottom of the hearth are cleaned once in every turn of twelve hours, and this is done by running in long bars to loosen the crust, which is then blown out with the steam generated from a bar which is dipped in water before it is thrust into the furnace.

Since the year 1854 the following figures have been published showing the number of furnaces built and in blast, with the total make of pig iron, and side by side appears the average make per furnace :—

Year.	Furnaces.		Pig Iron made.	Average per Furnace.
	Built.	In Blast.		
	No.	No.	Tons.	Tons.
1854	28	21	104,000	4,952
1855	28	20	101,500	5,575
1856	28	20	130,560	6,528
1857	28	23	134,057	5,827
1858	28	22	135,308	6,136
1859	29	23½	143,500	6,106
1860	31	25	146,950	5,878
1861	32	23½	187,700	7,987
1862	33	23	184,450	8,020
1863	33	25¼	176,504	6,854
1864	35	25	217,996	8,680
1865	35	27	206,268	7,640
1866	35	28⅓	210,335	7,432
1867	35	23	202,332	8,800
1868	36	25	229,913	9,196
1869	37	27	231,913	8,589
1870	43	36½	303,378	8,311
1871	35	31	268,300	8,655
1872	36	30¾	275,925	8,973
1873	39	31	283,103	9,132
1874	39	28	273,501	9,739
1875	39	26	241,398	9,284
1876	37	25	213,569	8,543
1877	35	25	255,383	10,215
1878	35	24	231,534	9,648
1879	35	23⅙	210,374	9,335
1880	36	23½	225,023	9,943

* Read before the New York Meeting of the American Institute of Mining Engineers, February, 1880. See "Colliery Guardian," 19th March, 1880, p. 448.

In the last named year, the works and firms in operation, with the number of furnaces built and in blast, were as follows:—

NORTH STAFFORDSHIRE IRON WORKS.

Name of Works.	Owners.	Furnaces.	
		Built.	In Blast.
		No.	No.
Apedale, Newcastle	Stanier and Co.	6	2
Silverdale ,,		2	2
Biddulph Valley	Robert Heath and Sons	4	4
Norton and Ravensdale	,, ,,	4	2
Chatterley, Tunstall	Chatterley Iron Co., Limited	3	1*
Clough Hall, Kidsgrove	Kinnersley and Co.	4	4
Goldendale, Stoke	Williamson Brothers	4	2
Lane End, Longton	Thos. Goddard and Son	2	0
Shelton, Hanley	The Earl Granville	5	4½
Longton Hall	J. and A. Glover	2	2
Total of North Staffordshire		36	23½

Malleable Ironworks, Mills, and Forges.—The most extensive of these in North Staffordshire are the Messrs. Robert Heath and Sons', situated at Biddulph Valley, Norton and Ravensdale, near Tunstall, possessing an aggregate of 154 puddling furnaces and 13 rolling mills. These works, when fully employed, are capable of producing from 1,500 to 1,600 tons of finished iron per week. The works of the Shelton Bar Iron Company are also of considerable magnitude, possessing upwards of 90 puddling furnaces and 8 rolling mills. The proprietor of these works is the Earl Granville, also chief owner of Lilleshall works in Shropshire, which establishment furnishes the best forge pig, largely employed in the Shelton Works. The works of North Staffordshire are justly celebrated for the superior quality of their plates, which are largely employed in our shipbuilding industries. In the manufacture of these the best Shropshire forge and hematite pig of the west coast is advantageously used.

In the year 1861 the only mills and forges in North Staffordshire were those of Messrs. Heath, the Shelton Bar Iron Company, and the Silverdale, of Messrs. F. Stanier & Co., possessing in the aggregate 139 puddling furnaces and 14 rolling mills. We have no indication of the state of activity in these works beyond the number of puddling furnaces and rolling mills in operation from

* One furnace for five months only.

year to year, together with the actual quantities of coal consumed in manufacture. The details under these heads are as follows, since the year 1870:—

Year.	Works.	Puddling Furnaces.	Rolling Mills.	Coal Used.
				Tons.
1870	8	406	38	*350,500
1871	8	429	40	*380,000
1872	8	446	41	460,000
1873	8	425	41	465,000
1874	9	454	42	369,801
1875	9	444	38	303,924
1876	9	433	39	299,235
1877	10	443	39	300,129
1878	10	385	38	295,184
1879	10	405	37	326,299
1880	10	350	34	314,015

The annexed table presents a complete list of the works in operation in the last named year, together with the number of puddling furnaces and rolling mills engaged in the manufacture of the various firms of bar and merchant iron. The works of Messrs. Heath possessing very powerful appliances for the manufacture of anchors:—

Name of Works.	Name of Firm.	Situated.	No. of Puddling Furnaces.	No. of Rolling Mills.
Biddulph Valley	Robert Heath and Sons	Tunstall	40	3
Norton, Ravensdale	" "	"	65	7
Chesterton†	Chesterton Coal and Iron Co., Limited	"	..	..
Chatterley†	Chatterley Iron Co.	"	..	..
Clough Hall, Kidsgrove	Kinnersley and Co.	Stoke	56	5
Shelton	Shelton Bar Iron Co.	"	87	8
Berry Hill	William Bowers	"	22	2
Cliff Vale	Joseph Bell and Son	"	24	3
Silverdale and Knutton	Stanier and Co.	"	56	6
Total of North Staffordshire			350	34

In the southern part of Staffordshire the same year there were 125 works, with 1,625 puddling furnaces and 311 rolling mills, consuming approximately 1,667,600 tons of coal.

Coal and Iron Ore used in Manufacture.—An interesting

* Estimated quantities. † Works standing.

statement, published in the year 1796, gives the following details of the quantity of coal consumed in raising coal, ironstone, and iron ore from the mine, and in the final completion of one ton of iron in rods for the manufacturer : *—

PURPOSES TO WHICH APPLIED.	Tons.	Cwts.
Small coal in the blowing engine	1	3
,, to torrify the raw material	0	11
,, to work the hammer engine	0	18
,, to work the mill engine	1	0
Large coal coked to be used in furnace	8	5
,, to refine the pig iron	1	2
,, in puddling furnace	1	3
,, in the heating furnaces	1	15
,, in the mill furnaces	0	7
,, in workmen's houses	1	5
,, in steam engines to draw the mine and draw the ironstone and coal	0	19
,, consumed in pitmen's houses	0	12
Total	19	0

From the above items it is estimated that the quantity of coal employed in the manufacture of a ton of pig iron was little short of 10 tons. In the year 1810 it appears, on the authority of Mr. Mushet, that the quantity did not exceed 5 tons. Again, in the year 1840, it is stated on the authority of Mr. William Jessop, of the Butterley Ironworks, that the quantity did not exceed 4 tons 1 cwt.

In the year 1854 a carefully written paper by Mr. John Hedley, of the Silverdale Works, on the "North Staffordshire Coal-fields," gives the following as the proportion of coal employed in those works in the manufacture of a ton of pig iron; namely, 42½ cwt. of coal, and 13 cwt. of slack, coked for the furnaces, with a further 19 cwt. of slack for the hot blast apparatus and blast engine, or a total of 74½ cwt. of coal to each ton of pig iron made.

Already the make of pig iron in North Staffordshire has been given. Since the year 1872 the quantities of coal and iron-stone used in the manufacture of pig iron have been ascertained, and afford reliable data for comparison; the quantities under each head appear in the annexed table :—

* Macnab. "Observations on the Coal Trade, &c., 1801," p. 69.

Year.	Pig Iron.	Coal used.	Iron Ore Used.
	Tons.	Tons.	Tons.
1872	275,925	817,753	723,400
1873	283,103	830,119	779,000
1874	273,501	820,514	752,600
1875	241,398	703,000	627,823
1876	213,569	525,387	562,348
1877	255,383	578,428	664,210
1878	231,534	530,594	612,326
1879	210,374	430,432	556,312
1880	225,023	434,171	569,334

In the year 1872 the quantity of coal used in the production of each ton of pig iron, all purposes in the operation included, where heat was required, gave an average of 59 cwt., and in the following year the average was somewhat less, indicating a watchful economy in the consumption of fuel.

Following the consumption of iron ore in each of the same years, 1872 and 1873, in the make of pig iron, the above quantities give an average of 52½ cwt. of raw uncalcined stone to each ton of pig iron obtained from the blast furnace; the greater proportion of the ore employed being native mine of the district. Other ores are also used in admixture, which are imported into the district, and the annexed statement will show approximately the places from which the ores were obtained:—

Source of Supply.	1872.	1873.	1876.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.
North Staffordshire . .	559,000	602,594	385,000	363,200	364,280
Oxfordshire	3,200	357	..	..	..
Northamptonshire . .	4,000	4,333 }	25,337	18,216	
Lincolnshire . . .	13,450	11,326 }			..
Various places . . .	143,750	160,390	152,011	174,896	205,054*
Total . . .	723,400	779,000	562,348	556,312	569,334

Of the ore derived from "various places" there is reason to believe that some portion of this quantity in each year is the produce of the district, the remainder being furnace mill cinder, containing a large percentage of metallic iron and some hematite from Lancashire.

With regard to the cost of production, it is stated that coal could be mined in 1877 in North Staffordshire at a little over

* Including some ore from Northamptonshire and Lincolnshire.

4*s*. per ton, and the ironstone from about 3*s*. to 3*s*. 6*d*. per ton. The work of getting is let out at so much per ton (averaging in 1877 from 2*s*. to 3*s*. per ton), the contractor employing miners whose daily wages average 4*s*. In the same manner, by taking the immediate wages at the blast furnace into consideration, a ton of pig iron could be produced at a little over 4*s*. a ton for labour. It will be remembered that wages have gone down since 1877, and if they have not yet reached the old figure, these approximate prices would have to be reduced still more to arrive at the present cost of production in this district.

An average charge of a furnace is as follows, the first being the quantities used for Red Shag alone, and the second for a mixture of Red Mine (raw giving 50 per cent.) and Lean Mine (raw giving 35 per cent.).

FIRST. Materials.	Cwt.	Qrs.	SECOND. Materials.	Cwt.	Qrs.
Coal	29	0	Coal	22	2
Ore	29	0	Red Mine	19	1
			Lean Mine	16	2
Limestone	2	2	Limestone	5	0
Flue cinder	1	3	Flue cinder	2	1

The consumption per ton of pig iron is practically as follows: Coal, 35 cwt. 3 qrs.; ironstone, 34 cwt.; limestone, 8 cwt. 2 qrs. and flue cinder, 4 cwt. 2 qrs.*

* "Transactions of the American Institute of Mining Engineers," Vol. VIII., p. 333.

CHAPTER XI.

SOUTH STAFFORDSHIRE AND WORCESTERSHIRE IRON INDUSTRIES.

Description of Ironstone Measures of Coal Field—Analyses and Production of Ironstone—Pig Iron Manufacture—Early History—Sturtevant, Ravenson, and Dudley's experiments in the Use of Coal previously coked—Production of Pig Iron—Coal and Iron Ore used in Manufacture—Calcination of Ores in Clamps and Kilns—Works in operation in 1880—Malleable Iron Works in 1880, coal used—Prices of Finished Iron.

Ironstone Deposits.—The measures yielding ironstone exist abundantly in this coal-field, with their associated beds of shale, in which fossils are found in great profusion. Professor Jukes, in his Introduction to Part II. of the "Iron Ores of Great Britain," remarks that it is the middle part of the coal-field which has ever been largely productive of ironstone, and in a general section of strata gives the following measures of ironstone and the varying thickness of the strata in which they occur:—

No.	General Section of Ironstone Measures.	Thickness.
		Feet.
I.	Brooch Binds	7 to 20
II.	Pins and Pennyearth	6 ,, 30
III.	Broad Earth, Catch Earth, &c.	6 ,, 14
IV.	Pouncill Batt, Blacktery, and Whitery . .	2 ,, 8
V.	Gubbin, called "Little" or "Top" . . .	2 ,, 8
VI.	New Mine or White Ironstone , . . .	2 ,, 10
VII.	Measures containing Pennystone, Ironstone, called also Bluestone or Cakes . . .	10 ,, 25
VIII.	Measures containing the Fire-clay balls, ironstone occasionally	2 ,, 40
IX.	Getting Rock Ironstone (occasional) . . .	4 ,, 5
X.	Poor Robin Ironstone	3 ,, 5
XI.	Rough Hills White Ironstone (occasional) . .	2 ,, 19
XII.	Gubbin and Balls Ironstone	0 ,, 10
XIII.	Blue Flats Ironstone	2 ,, 9
XIV.	Silver Threads	4 ,, 7
XV.	Diamonds	2 ,, 3

It must not, however, be supposed that all these measures are found vertically one under the other in any one part of the coal-

field. The uppermost are known only in the southern extremity, where they dip to the south. The lowest are either altogether absent there, or do not contain the measures which, a few miles further north, are rich in ironstone. Towards the north, on the other hand, the lowest measures "crop out" or rise towards the surface, and it is therefore not possible that the upper measures should be found there. The section given above is compiled partly from the examination of the southern, partly of the middle, and partly of the northern part of the district, the object being to enumerate every important measure of ironstone and its relative position in the coal-field.

Professor Jukes * gives the following description of the above-named ironstone measures, which it will be convenient to take in the order of occurrence:—

I. Brooch Ironstone, or *Binds*—are beds of clay or shale beneath the Brooch coal, containing ironstone to the south-west of Dudley, where the measures average about 7 feet in thickness.

II. Pins and Pennyearth.—These measures take their name from the form of the nodules in which the ironstone occurs. The "Pins" being small, round or cylindrical, and the "Pennyearth," small, flattish nodules, like pennypieces.

III. The "Ten-foot Stone," and *"Backstone."*—Known also as the Broad Earth, &c., so called from lying immediately above or on the back of the "Thick Coal," in the neighbourhood of Brierley Hill.

IV. The "Whitery," or *Grains.*—These are merely occasional ironstone measures, consisting of light and dark coloured clunch, a term applied to course tough clay of the coal measures. These measures are sometimes absent, and where they contain most ironstone rarely exceed 6 or 8 feet in thickness.

V. Gubbin.—Sometimes called the "Little," or "Top," or "Thick Coal Gubbin," is one of the most important and widely diffused of the ironstone measures of this coal-field, and yields an average of 1,500 tons per acre, the thickness of the measures varying in different places from 2 to 9 feet.

VI. New Mine Ironstone, or *Whitestone.*—This is another widely diffused ironstone; it is a light coloured ironstone, occurring in large nodules lying in a bed of clay, which is called

* "Iron Ores of Great Britain," Part II., p. 108.

"clunch," "clod," or "binds," according to its minor varieties. The layers of nodules vary from 2 to 4 feet, and the whole measure from 2 to 10 feet in thickness, the most usual being from 4 to 5 feet. Professor Jukes gives several interesting sections, at Wolverhampton, Bilston, Dudley and Kingswinford, in which these measures occur and from which the above average thicknesses are derived.

VII. Pennystone Bluestones, or "*Cakes.*"—The measures in which this ironstone lies are dark clay, sometimes black, the ironstone occurring in flat, round nodules of a dark colour. In the district of Dudley, to the south-west, ironstone has rarely if ever been found on this horizon, or below it, while it is well-known towards Oldbury, under the names of "Cakes," or "Bluestone," and between Wolverhampton and Walsall as Pennystone.

VIII. "*Fire-Clay Balls.*"—This measure is variable and capricious, and the ironstone irregular in its occurrence, and in the form of balls, hence the name, and resting on the fire-clay coal. In the Stow Heath and Priestfield Collieries, between Bilston and Wolverhampton, where there are many pits within the space of half a mile, these measures vary from a seam of clay 2 or 3 feet in thickness to a mass of sandstone 39 feet thick, with a little fire-clay above and below it.

IX. "*Getting Rock Ironstone.*"—This measure, occurring below a bed of fire-clay, varying from 2 to 10 feet in thickness, sometimes contains ironstone worth working in certain localities. It appears to be confined to the neighbourhood of Stow Heath, Ettingshall, Deepfields, and Bradley, and does not always occur even there.

X. "*Poor Robin.*"—This ironstone is more widely diffused and persistent than that of the Getting Rock; the measure is sometimes 3 and 4 feet thick.

XI. "*Rough Hills Whitestone.*"—This ironstone is confined to the district between Bilston and Wolverhampton. At Parkfields the measures are 19 feet thick, containing 11 bands of ironstone from 1 to 6 inches thick, making a total of 32 inches of ironstone. Elsewhere it is not so fully developed, not exceeding 3 or 4 feet thick, with not more than from 6 to 8 inches of ironstone.

XII. "*Gubbin and Balls.*"—This measure contains good workable ironstone, occurring principally between Wolverhampton and Walsall and around Bilston. At Chillington Colliery the

thickness of the measures is nearly 7 feet, with 4 bands of ironstone, giving a total thickness of 23 inches.

XIII. "*Blue Flats.*"—This ironstone is so called from the flat pavement-like form in which it occurs. At Park Hall, just south of Wolverhampton, in a section of 8 feet 9 inches of measures, are 4 bands of ironstone, giving an aggregate thickness of 16 inches; while at Ryecroft, near Walsall, the measures are found in a thickness of 18 inches, with 2 bands of ironstone each 3 inches thick.

XIV. "*Silver Threads.*"—This measure occurs in the district around Walsall, varying from 4 to 7 feet thick, composed of 2 or 3 bands of ironstone, varying from 1 to 4 inches in thickness, and so named from the little threads of shining spar, which traverse the ironstone.

XV. "*Diamonds.*"—This ironstone, the lowest in the series, is confined, like the Silver Threads, as a workable ironstone, to the district west of Walsall, where it occurs from 2 to 4 feet thick, and contains 2 bands of ironstone varying from 2 to 4 inches in thickness.

Analyses of the Ironstone.—In the "Iron Ores of Great Britain," Part II., from which the account of the principal ironstone measures are taken, also appear complete analyses of no less than 30 of the ironstones wrought in the South Staffordshire coal-field. These analyses were made in Dr. Percy's laboratory, and subsequently published in the Memoirs above referred to. It will be sufficient, however, to give a description and analysis of some of the more important and characteristic ironstones of the several districts. Those selected in the Dudley district are thus described:—

The "*Grains,*" (No. IV. of General Section). By Mr. A. Dick. —"Clay iron ore; colour, greyish black; structure, compact and homogeneous. The ore is covered in some places with a thin layer of yellowish white matter."

"*Gubbin Ironstone,*" (No. V. of General Section). By Mr. A. Dick.—"Clay iron ore; colour, greyish black; structure, compact and homogeneous. It contains thin veins of white and reddish brown matter, in which zinc-blende, galena, and copper pyrites occur."

"*Fire-Clay Balls,*" (No. VIII. of General Section). By Mr. A. Dick.—"Fine grained, crystalline, carbonate of protoxide of

iron; colour, greyish brown. It contains veins of calc spar and white pulverulent silicate of alumina, in which occur small, white, crystalline, globular concretions, consisting of carbonate of lime and magnesia.

RESULTS TABULATED.*

Constituents.	Grains.	Gubbin.	Fire Clay Balls.
Protoxide of iron	54·12	45·86	47·87
Protoxide of manganese	2·05	0·96	1·12
Alumina	0·78	0·42	0·43
Lime	2·21	1·17	1·00
Magnesia	0·62	1·65	1·27
Potash	trace	...	...
Carbonic acid	35·25	31·02	30·96
Phosphoric acid	0·69	0·21	0·07
Sulphuric acid	trace	trace	0·08
Silica	2·11	0·42	...
Bisulphide of iron	0·40	0·10	0·17
Water	1·07	1·08	1·18
Organic matter	1·36	0·90	0·41
Ignited insoluble residue	...	15·90	15·95
Total	100·66	99·69	100·51
IGNITED INSOLUBLE RESIDUE.			
Silica	...	10·26	10·52
Alumina	...	5·44	5·02
Peroxide of iron	...	0·40	0·33
Lime	...	0·20	0·13
Magnesia	...	0·20	...
Potash	...	...	0·38
Total	3·43	16·50	16·38
Metallic iron	42·26	35·99	37·47

In a note appended to the analysis of the "Grains," it is stated no separate examination of the insoluble residue was made; and further, that no metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution was detected in 900 grs. of this ore, 500 grs. of the Gubbin, or 750 grs. of the Fire-clay ore.

In the Darlaston district the measures examined by Mr. Charles Tookey, from the Rough Hay Colliery, are thus described:—

"*Rough Hill Whitestone,*" (No. XI. of General Section).—"Clay iron ore; colour, brown; structure, compact and homo-

* "Iron Ores of Great Britain," Part II., pp. 120, 123, 139.

geneous. Veins of hydrated silicate of alumina, peroxide of iron and copper pyrites occur in it."

"*Gubbin and Balls*," (No. XII. of General Section).—"Clay iron ore; colour, greyish black; structure, compact. It is seamed with greyish white silicate of alumina, in which minute crystals of zinc-blende, iron pyrites and copper pyrites occur."

"*Silver Threads*," (No. XIV. of General Section).—"Clay iron ore; colour, greyish brown; the ore is irregularly seamed, with numerous veins of calcspar, coated with drab coloured ferruginous matter."

"*Diamonds*," (No. XV. of General Section).—"Clay iron ore; colour, dark grey; structure, compact and homogeneous. It contains veins of calcspar and silica of alumina, in which galena, zinc-blende, copper pyrites and iron pyrites occur."

RESULTS TABULATED.

Constituents.	Rough Hill Whitestone.	Gubbin and Balls; Gubbin.	Silver Threads.	Diamonds.
Protoxide of iron . .	46·56	49·30	40·39	40·01
Peroxide of iron . .	2·80	3·61	2·38	2·46
Protoxide of manganese.	0·65	0·86	0·75	0·75
Alumina	0·70	0·34	0·19	0·46
Lime.	1·13	0·69	7·30	2·58
Magnesia	1·18	0·45	2·16	2·70
Silica	0·54	0·23	0·18	0·27
Potash	0·23	0·09	0·07	0·19
Carbonic acid . . .	30·08	32·05	33·35	29·13
Phosphoric acid . .	0·38	0·23	0·22	0·21
Bisulphide of iron . .	0·13	0·13	0·11	0·06
Sulphide of zinc . .	...	1·27	...	...
Water	1·07	0·66	0·93	1·11
Organic matter . .	0·50	0·54	0·80	1·06
Ignitedinsolublesolution	13·77	9·42	10·52	18·77
Total . . .	99·72	99·87	99·35	99·76
IGNITED INSOLUBLE RESIDUE.				
Silica	7·72	5·99	6·56	13·45
Alumina	4·70	2·71	3·08	4·22
Peroxide of iron . .	0·39	0·21	0·37	0·59
Lime	0·11	0·17	0·04	0·08
Magnesia	0·15	0·07	0·06	0·14
Potash	0·82	0·21	0·26	0·18
Total . . .	13·89	9·36	10·37	18·66
Metallic iron . . .	38·56	41·06	33·44	33·28

The presence of copper was distinctly proved in 800 grains of the "Rough Hill Whitestone" ore. In the "Gubbin and Balls," and the "Silver Threads," no metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution was detected in 400 grains of the former and 800 grains of the latter; while in the "Diamonds" traces of lead and copper were found in the hydrochloric acid solution of 800 grains of ore.

There is also an ironstone known as "Brown Stone," occurring in the neighbourhood of Bloxwich, some three miles north of Walsall, not previously referred to, which is described as a "Clay iron ore; colour, various shades of light brown; structure, compact. Veins of white pulverulent and grey crystalline substances occur in it, containing traces of galena and copper pyrites." The analysis of this ore, by Mr. A. Dick, gives the following results:—*

RESULTS TABULATED.—ORE DRIED AT 100° C.

Protoxide of iron	46·14
Protoxide of manganese	1·40
Alumina	3·53
Lime	3·43
Magnesia	2·13
Potash	0·41
Carbonic acid	32·04
Phosphoric acid	0·61
Sulphuric acid	trace.
Silica	8·63
Bisulphide of iron	0·10
Water	0·94
Organic matter	0·98
	100·34
Metallic iron	35·95
Clay after ignition	13·38

It is stated in reference to this analysis that no metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 550 grains of the ore was detected.

Of the ironstone measures examined and published in the "Iron Ores of Great Britain," Part II., some thirty analyses appear; and from these the following abstract has been prepared showing the relative proportion of protoxide of iron, phosphoric acid and metallic iron contained in each sample examined; preceding which is given the name of each measure and the analysts who examined it.

* "Iron Ores of Great Britain," Part II., p. 164.

IRONSTONE MEASURES OF SOUTH STAFFORDSHIRE.

Clay Iron Ores.	Analyst.	Protoxide of Iron.	Phosphoric Acid.	Metallic Iron.
Brooch, Corngreaves	John Spiller	43·81	0·83	34·35
Pins, Dudley	Allan Dick	45·35	0·46	35·74
Penny Earth, Dudley	,,	37·69	0·66	29·42
Grains, Dudley	,,	54·12	0·69	42·26
Gubbin, Dudley	,,	46·30	0·74	36·14
Gubbin, Rubble, Dudley	,,	40·28	0·30	31·70
Whitestone Bind, Dudley	John Spiller	30·96	0·26	24·88
Bottom Whitestone, Dudley	,,	48·63	0·31	37·45
Whitestone, Darlaston	Charles Tookey	33·92	0·35	28·87
Cakes or Bluestone, Dudley	Allan Dick	50·60	0·23	39·71
,, ,,	,,	43·55	0·15	34·88
Fire-clay Balls, Dudley	,,	46·39	0·11	36·56
,, ,,	,,	47·87	0·07	37·47
Poor Robin's, Bunker's Hill	,,	49·61	0·34	39·62
Rough Hill Whitestone, Darlaston (good sample)	,,	44·20	0·66	34·53
,, ,, (bad sample)	,,	33·19	0·50	26·01
Rough Hill Whitestone, Rough Hay, Darlaston	Charles Tookey	46·56	0·38	38·56
Gubbin and Balls, Bunker's Hill Colliery	Allan Dick	39·51	0·31	31·34
,, ,, ,,	,,	52·04	0·21	40·84
Blue Flats, Darlaston	Charles Tookey	42·34	0·25	34·41
Silver Threads, Darlaston	,,	40·39	0·22	33·44
Diamonds, Darlaston	,,	40·01	0·21	33·28
,, ,,	Allan Dick	41·90	0·22	32·87
Brownstone, Bloxwich	,,	46·14	0·61	35·95

From these and other analyses of the argillaceous ores of the district, it has been ascertained that 34·75 per cent. represents the average yield of metallic iron.

Production of Ironstone.—The production of ironstone in South Staffordshire was returned as follows, in each of the years named:—

Year.	Tons.	Year.	Tons.
1859	959,000	1870	450,000
1860	785,700	1871	705,665
1861	727,500	1872	640,950
1862	700,500	1873	584,325
1863	850,000	1875	715,451
1864	948,500	1876	645,288
1865	659,500	1877	636,243
1866	599,000	1878	587,874
1867	525,000	1879	483,507
1868	340,578	1880	362,773

For a few years the individual returns of ironstone were published, those for the year 1873 are at hand and were as follows; since 1875 the aggregate production is alone recorded:—

District or Mine.	Quantities.	Value.
	Tons.	£ s.
Barbor's Field	11,011	6,006 12
Barn Farm	2,690	1,560 0
Birchill's Hall	6,206	3,723 12
Bradley	1,897	1,138 4
Cannock Chase	350	210 0
Coppy Hall	9,189	5,513 8
Deans	5,287	3,172 4
Friar Park	5,614	3,368 8
Grace Mary	2,645	1,587 0
Granville	3,695	2,217 0
Haden Hall	6,480	3,888 0
Hatherton	8,298	4,978 16
Jervoise	2,122	1,273 4
Moxley	1,880	1,128 0
New Cross	15,503	9,301 16
Old Hall	7,100	4,260 0
Parkfields	5,073	3,043 16
Priestfields	3,735	2,241 0
Princes End	3,118	1,870 16
Pearson	2,125	1,275 0
Riddings	2,168	1,300 16
Roughwood	7,045	4,227 0
Stow Heath	9,404	5,640 0
,,	11,312	6,787 4
Shut End	3,971	2,382 12
Tansey Green	2,073	1,243 16
Tipton Moat	6,374	3,824 8
Wednesbury	5,232	3,139 4
Wednesbury Oak	4,000	2,400 0
Yeatham	5,541	3,324 12
Sundry pits	73,191	43,914 12
,, (estimated)	350,004	210,000 0
Total of South Staffordshire	584,325	349,941 10

The value of these ironstones, between 1860 and 1870, varied from 5*s*. to 6*s*. and 7*s*. 6*d*. per ton; the average price in 1880 being 10*s*. per ton.

Pig Iron Manufacture.—The history of the manufacture of iron may be regarded as of two distinct periods—the one extending from the earliest times when charcoal was alone employed; the other commencing with the successful application of coal previously coked, and dating about the year 1735. In the early part of the 17th century the rapid devastation of our forests occasioned great scarcity in the supply of charcoal to our furnaces, so much so, that three-fourths of the blast furnaces in the kingdom came to a standstill; it was at this period that

attention was directed to the use of coal previously coked. In 1612 we find Simon Sturtevant, and again in 1613 Ravenson, working towards this end; they were unsuccessful; in 1620, however, the use of mineral fuel was proved practicable in the reduction of the ores of iron, and we find Dud Dudley, the founder of the noble house of Dudley, to whom a patent was granted in the same year for smelting iron ore with pit or sea coal, to have so far succeeded as to have made 3 tons of pig iron from a furnace in a week with coke. Dud Dudley, in his book "Metallum Martis," published in 1665, gives an interesting account of his labours and the difficulties encountered by him. His works were swept away by a great flood; he further tells us that they were repaired, and at a subsequent period riotously destroyed, and he himself utterly ruined by adhering to the royal cause, which disturbed society in those days. With this historical reference we advance to the year 1735, when the successful application was carried out by Mr. Abraham Darby, of Shropshire, at the Coalbrookdale Works, and from this period may be dated the first great improvement in the manufacture of pig iron.

Metallica also reprinted 1855 in same volume

John Rovenzon A Treatise on Metallica Reprinted, Wolverhampton 1855.

The ! A natural son of Edward, 5th Lord Dudley

Reprinted with Sturtevant & Rovenson in 1855

In the year 1740, when the production of charcoal pig iron amounted to 17,350 tons, there existed in South Staffordshire 2 furnaces, and a like number in Worcestershire, producing 1,700 tons of pig iron: the two former making 1,000 tons and the latter 700 tons. Advancing to the year 1788 the manufacture of pig iron with charcoal appears to have been discontinued and coke substituted; for we find 3 furnaces in operation in South Staffordshire, producing 2,400 tons of coke pig iron.

The total production of pig iron at this period in England and Wales was:—

Description.	Furnaces.	Tons.
	Nos.	
Charcoal iron	24	13,100
Coke iron	53	48,200
Total	77	61,300

Some twenty years after the successful application of coal by Darby in the reduction of the ores of iron in the furnace, a new impulse was given to this industry by Smeaton's invention, in

which he applied, with great advantage, his blowing cylinders, worked by water-wheels or by the atmospheric steam engine; the first of these was erected by him at the Carron Ironworks in Scotland in 1760. This means of increasing the power of the blast in the furnaces was quickly followed by increased production of pig iron.

Again, towards the close of the last century a new era in the manufacture of iron arose, when the steam engine, the invention of James Watt, was made general in its application to the purposes both of pumping water from mines and for increasing the intensity of the blast. Cort's inventions, for which he obtained patents in 1783 and 1784, formed another important step in the manufacture of wrought from pig iron, the first for puddling, by which pig iron is rendered malleable, and the second for substituting rollers for the forge hammer for drawing out the balls of malleable iron into bars. The foregoing advantages, together with the high price of foreign iron, largely imported, caused our manufacture to nearly double itself between the years 1788 and 1796, to which latter year attention is now directed. The return for 1796 was prepared for the House of Commons, when Mr. Pitt had it in contemplation to impose a tax on coal at pit's mouth, and the returns were obtained from three sources—the Excise authorities, calculation, and lastly, the quantities really made. The works then existing in South Staffordshire and Worcestershire, with the number of furnaces and make of each works are stated as follows, giving an average yield per furnace of 937 tons:—

Works.	Number of Furnaces.	Excise.	Calculated.	Actual.
		Tons.	Tons.	Tons.
Bilston	2	2,340	2,340	1,429
Bradley	3	3,640	3,000	1,920
Brierley	1	1,300	1,300	1,046½
Deepfield	2	2,600	2,600	2,526
Dudley Port	1	1,040	1,040	869
Gospel Oak	1	...	...	1,613
Graveyard	1	1,260	1,336	213
Level	1	1,560	1,560	1,391
Tipton	2	2,082	2,080	2,203
Total . . .	14			13,210½

In the same year, 1796, the production of Great Britain, of

124 furnaces, amounted to 125,079 tons, of which South Staffordshire contributed upwards of 10 per cent. The returns for the year 1806 show a considerable increase, the 105 furnaces in blast in that year in Great Britain yielding 243,851 tons of pig iron, the production of South Staffordshire being 47,592 tons, or an increase of nearly 400 per cent., when compared with the returns for 1796. The following statement shows the individual production of the ironworks in 1806, with the respective numbers of furnaces built and in operation :—

Works.	Furnaces.		Pig Iron.
	Built.	In Blast.	
	Nos.	Nos.	Tons.
Blower's Green . . .	1	1	2,436
Bilston	3	2	3,550
Bradley	3	2	2,566
Brierley Hill . . .	1	1	817
Brierley	2	0	...
Caponfield	2	2	4,600
Deepfield	2	2	3,660
Dibsdale Bank . .	1	1	300
Dudley Port . . .	1	1	1,196
Golden Cross . . .	1	1	184
Gornal Wood . . .	1	1	432
Graveyard	2	1	1,274
Gospel Oak . . .	2	2	4,667
Level	3	2	3,351
Mill Field	2	2	5,000
Moorcroft	2	1	1,955
Netherton	2	1	1,500
Oldbury and Tipton .	3	3	4,500
Park Head . . .	1	1	1,404
Rough Hill	2	2	3,000
Toll End	2	1	1,200
Wednesbury	1	0	...
Total . . .	40	30	47,592

The production of Shropshire and South Wales alone exceeded that of South Staffordshire at this period, the former yielding 54,966 tons, the latter 68,867 tons, while that of Scotland was but 22,840 tons of pig iron. The next return from which information is obtained was prepared for the Government by Mr. F. Finch, formerly member for Walsall, and refers to the production in the years 1823 and 1830, when the number of furnaces in blast and the quantity of pig iron made in this district was as follows :—

SOUTH STAFFORDSHIRE.

—	Furnaces.	1823.		1830.	
		Total Number of Furnaces.	Pig Iron Made.	Total Number of Furnaces.	Pig Iron Made.
			Tons.		Tons.
1	Bradley	2	4,195	2	4,194
2	,, Lower	1	1,920	1	2,113
3	Birch Hills	2	...	2	...
4	Barbor's Field	...	...	2	5,720
5	Bilston	4	7,696	4	4,680
6	,, Brook	2	4,345	2	3,771
7	Broadwaters	2	...	...	6,368
8	Brettell Lane	...	...	2	2,949
9	Brierley Hill	2	4,348	2	...
10	Blower's Green	2	5,348	2	5,257
11	Buffery	3	6,551	3	5,246
12	,, Old	1	2,646	1	2,158
13	Cotham	...	...	...	...
14	Coseley	2	5,200	3	10,140
15	Caponfield	2	...	2	...
16	Chillington	...	...	2	6,240
17	Corbyn's Hall	...	...	4	7,350
18	Dudley Port	1	2,340	1	2,340
19	,,	...	...	2	4,060
20	Deepfield	2	...	2	...
21	Deepdale	1	2,084	1	1,634
22	Dudley Wood	4	10,467	4	8,664
23	Eagle	2	4,900	2	6,656
24	Fiery Holes	1	...	1	1,634
25	Glebe	1	...	1	...
26	Gospel Oak	2	5,312	4	6,840
27	Gold's Green	2	4,888	3	9,412
28	Graveyard	1	...	1	...
29	Gornal Wood	1	1,671	1	...
30	Horseley	2	4,308	2	4,680
31	Hale Fields	1	2,454	1	2,454
32	High Fields	2	...	2	...
33	Lea Brook	1	...	1	...
34	Leys	...	...	2	4,160
35	Level	4	6,464	4	...
36	,, Old	1	2,072	1	1,028
37	Mill Fields	4	6,768	4	8,112
38	Moorcroft	2	3,700	2	4,791
39	Netherton	2	1,406	2	5,033
40	Oldbury	2	2,600	2	5,720
41	Old Park	1	2,600	2	5,280
42	Priestfield	3	3,664	3	4,897
43	Parkfield	...	...	4	9,500
44	Parkhead	1	2,289	1	2,468
45	Rough Hills	2	...	2	...
	Carried forward	71	112,236	92	164,549

SOUTH STAFFORDSHIRE—*continued.*

—	Furnaces.	1823.		1830.	
		Total Number of Furnaces.	Pig Iron Made.	Total Number of Furnaces.	Pig Iron Made.
			Tons.		Tons.
	Brought forward	71	112,236	92	164,549
46	Russell's Hall	...	...	2	2,080
47	Stow Heath	...	...	3	5,408
48	Toll End	3	5,075	3	6,112
49	Tipton Company	3	5,640	3	3,515
50	Tipton	1	2,040	1	2,040
51	Union	...	...	2	4,650
52	Wednesbury Oak	2	6,240	3	7,684
53	Willingsworth	...	...	3	5,704
54	Wolverhampton	...	...	2	3,200
55	Walbrook	1	2,359	2	2,886
56	Windmill End	...	...	2	3,776
	Total	81	133,590	118	211,604

Showing an increase in seven years of 37 furnaces and 79,014 tons of pig iron, or an increase of 58 per cent. The average yield per furnace in 1823 being 1,640 tons, compared with 1,793 tons in 1830. The works at Barbor's Field were erected between the years 1826 and 1828, and the undermentioned as follows :—

Works.	Year.	Works.	Year.
Brettle Lane	1825	Stow Heath	1824 and 1825
Chillington	1829	Union	1828
Corbyn's Hall	1825 and 1829	Willingsworth	1827 and 1828
Dudley Port	1824	Wolverhampton	1824 and 1826
Levels	1828	Windmill End	1825
Parkfield	1825 and 1827		
Russell's Hall	1827		

We have now reached a period when the hot blast was coming into use; this invention of Mr. Neilson was first successfully employed in the furnaces of Scotland, and gradually extended into other iron-making districts.

In 1830, when the production of South Staffordshire was 211,604 tons, Scotland produced but 37,500 tons; while the total make of the furnaces in Great Britain did not exceed 652,417 tons.

The number of furnaces built and in blast, the make of pig iron, and the average yield per furnace appear in the annexed table :—

SOUTH STAFFORDSHIRE AND WORCESTERSHIRE.

Year.	Furnaces.		Production of Pig Iron.	Average make per Furnace.
	Built.	In Blast.		
	Nos.	Nos.	Tons.	Tons.
1840	135	116	407,150	3,510
1847	139	77	320,320	4,070
1851	148	105	600,000	5,714
1852	159	127	725,000	5,693
1854	175	145	743,600	5,128
1855	178	146	754,000	5,164
1856	171	147	777,171	5,287
1857	180	153	657,295	4,300
1858	186	147	597,809	4,067
1859	184	123	475,300	3,864
1860	181	108	469,500	4,347
1861	182	114	395,650	3,470
1862	191	107	610,220	5,703
1863	200	110	691,157	6,283
1864	176	106	628,973	5,934
1865	172	114	692,627	6,075
1866	167	112	532,625	4,755
1867	177	91	515,638	5,666
1868	172	89	532,234	5,980
1869	164	95	569,562	5,995
1870	171	114	588,540	5,163
1871	163	108	725,716	6,720

Coal and Iron Ore used in Manufacture.—Since the year 1872, information under both these heads is available; it will, therefore, be convenient to tabulate the returns of production of pig iron in each year since that date, and follow with the quantities of coal and iron ore of all kinds employed; the returns are as follows:—

Year.	Furnaces.		Pig Iron Made.	Coal Used.	Iron Ore, &c., Used.
	Built.	In Blast.			
	Nos.	Nos.	Tons.	Tons.	Tons.
1872	145	107	673,470	1,932,509	1,800,000
1873	142	99	673,397	1,968,580	1,800,000
1874	154	81	452,400	1,309,216	1,195,600
1875	155	76	474,540	1,353,850	1,268,000
1876	147	65	465,946	1,262,962	1,235,000
1877	146	57	428,276	1,032,419	1,123,500
1878	147	55	392,949	917,106	1,005,900
1879	140	44	325,780	743,006	830,500
1880	137	45	384,556	878,581	984,500

In the beginning of the present century the average quantity of coal required in the manufacture of a ton of pig iron was ten tons. About the year 1810, Mr. R. Mushet states, in his valuable papers on iron and steel, that half this quantity enabled the ironmaster to produce a ton of pig iron. After the introduction of the hot blast by Mr. J. B. Neilson, the economy in the consumption of fuel becomes more apparent, for we learn that in the year 1840, on the authority of Mr. William Jessop, that the quantity did not exceed 3 tons 17 cwt. in the works of South Staffordshire; while the average used in Great Britain the same year was but 4 tons 1 cwt., compared with 10 tons in the year 1800. In the year 1869 the Royal Coal Commission reported on this important question, and ascertained that a further economy had been secured, 3 tons of coal only being required.

In the years 1871 and 1872 the average quantity of coal used in South Staffordshire was about 58 cwt. In the furnaces of Great Britain in each of the same years the average was 51 cwt.; while in Scotland, where raw uncoked coal is principally used, 55 cwt. of coal was required to each ton of pig iron made.

In most of our iron making districts the waste gases are utilised and great economy secured; here, however, in South Staffordshire, but few furnaces were provided with gas saving apparatus (these arrangements are now being more generally employed), and hence the increased consumption of coal with other districts comparatively.

Of the coal employed in iron making, the "Thick Coal" and the Heathen Coal are the most important, the former giving, when coked, 54 per cent., with 0·31 of sulphur and 4·18 of ash; the latter between 40 and 45 per cent. of coke, 0·51 of sulphur, and 4·58 of ash; while generally, in the district, the coal is used partly raw and partly coked.

The "Native Mine," or clay ironstone of the coal measures of this district, if alone employed, would require from 54 to 55 cwt. of raw uncalcined ore, to each ton of pig iron made, a smaller quantity being required when richer ores used in admixture are employed. It was ascertained approximately, that in the years 1872 and 1873 the quantity of iron ore of all kinds used in the manufacture of 673,470 tons of pig iron was 1,800,000 tons in each year, the following districts furnishing quantities in the proportion given:—

DISTRICTS.	TONS.
South Staffordshire	600,000
North Staffordshire	550,000
Lancashire	55,000
Northamptonshire	230,000
Oxfordshire	19,000
Various ores	206,000
Forge and mill cinder	140,000
Total Ore	1,800,000

The quantity classed as "various ores" includes ores from Wales, Warwickshire, Gloucestershire, Cleveland, and elsewhere, but it has not been possible to distinguish the proportion received from each district. As previously stated the "Native mine" of this district yields an average of 34·75 per cent. of metallic iron, compared with the ironstone of North Staffordshire, which gives 36·50 per cent., and the Churnet Valley ore nearly 37 per cent. The Northamptonshire and Oxfordshire ores, hydrated peroxides so valuable in admixture with the coal measure ores as a flux, their siliceous character not being injurious, yield 40 per cent. of metallic iron, the hematite of Lancashire about 64 per cent., and the forge and mill cinders probably not less than 50 per cent. These cinders are largely employed in the production of common hot-blast pig, while the best mine pig, for which Staffordshire is so justly celebrated, is made from "Native mine," and other selected ores, coal previously coked, and cold air in the blast furnace.

In the calcination of the ironstone two modes are practised, namely, in clamps and kilns. In clamp calcining it is customary first to spread a layer of coal in lumps upon the ground and on this to raise the heap of ironstone, interspersing coal occasionally, and then to cover the surface of the heap with slack. In the calcination of "black band," the carbonaceous matter it contains is sufficient to effect the operation. The "heaps," or "clamps" are made from 6 to 8 feet high, and vary considerably in area, sometimes having an area of half an acre.

In the operation, as in brickmaking, the calcined stone is being removed from one end while the heap is being freshly made at the other end. The heap being ignited burns through in a smouldering way, emitting a good deal of smoke, a little flame breaking through the surface in places. An ordinary-sized clamp takes about three weeks to become thoroughly calcined, and at the end

of this time it is found to be reduced to about one half its original bulk.

For calcining in kilns an ordinary open kiln, like a common egg-shaped lime-kiln, is sometimes used; but for the most part iron cup-shaped kilns, made of iron plates lined with fire-brick, are employed. They are about 24 feet in height, and so arranged that while the ore and fuel can be fed in continuously above, the calcined ore is discharged at the bottom, either upon a raised platform or directly into the waggons that are to carry it away. The kiln once ignited, all that is necessary is from time to time to throw in a layer of coal on the top of a charge of stone.

The forge and mill cinder often used as a material for the smelting of pig iron and producing a variety of iron known as "cinder iron," which is made to some extent in South Staffordshire, calls for a brief notice. The "tap cinder," * as described by Dr. Ballard, "is the slag drawn out from puddling furnaces in which pig iron has been made into malleable iron. It consists mainly of protoxide of iron and siliceous matter, the latter partly derived from the bricks with which the reverberatory furnace is lined. In fact, it is the bath of 'fettle,' rich in peroxide of iron, which in the process of puddling has given up its excess of oxygen to oxidise the carbon, silicon, sulphur, and phosphorus which the pig iron contains, and which have, in the process of puddling, to be, as far as practicable, removed. The tap cinder, in order to fit it again for use in fettling, requires that the iron it contains should be peroxidised."

In either case the "tap cinder" requires calcination when it is employed for "fettling," that is, for lining puddling furnaces. With the object above described the calcination is performed in what is termed a "bull dog" kiln, the resulting material going under the technical designation of "bull dog." A bull dog kiln is constructed very much like a Scotch brick-kiln, 9 or 10 feet high, with side walls, having opposite fire openings at intervals, and the tap cinder to be calcined is first built up at the bottom so as to form channels or passages from the fire openings on one side to those on the other. The cinder, broken up, is then filled in with alternating layers of coal up to the top of the kiln. The ends are bricked up and the kiln lighted. It burns out in about

* Local Government Board. Eighth Report, 1878-79, p. 238.

a week. The fire should not be too fierce or the tap cinder merely melts down and may then form a hard mass which can scarcely be extracted except by blasting. When the kiln has gone out, the calcined material or "bull dog" is found in a coherent mass, which has to be broken down with a pick. For making cinder iron it is usual to calcine the cinder in a large clamp or heap, frequently 25 feet high, and containing many thousand tons. The heap is made much in the same way, with coal at the bottom and interspersed, as an ironstone clamp; the average consumption of fuel being about 6 or 7 cwt. to each ton of cinder, the heaps usually burning out in about a fortnight.

The most recent statement showing the works, furnaces built and in blast in South Staffordshire, appears as follows for the year 1880:—

South Staffordshire.

No.	Name of Works.	Owners.	Furnaces.	
			Built.	In Blast.
			Nos.	Nos.
1	Barbor's Field, Bilston	Barbor's Field Co.	2	1
2	Bovereux, "	Thomas Holcroft	2	1
3	Deepfields, "	Deepfields Iron Co.	3	0
4	The Brook, "	The Brook Furnaces Iron Co.	3	0
5	Herbert Park, "	David Jones & Sons	1	0
6	Prior Field, "	H. B. Whitehouse & Son	3	3*
7	Millfield, "	W. and J. S. Sparrow & Co.	3	1
8	Spring Vale, "	Alfred Hickman	4	4†
9	Capponfield, "	John Bagnall & Sons, Limited	3	1
10	Horseley Fields, Wolverhampton	Osier Bed Iron Co.	3	0
11	Old Park, "	Wolverhampton and Staffordshire Banking Co.	3	0
12	Chillington, "	Chillington Iron Co., Limited	4	0
13	Gold's Hill, West Bromwich	John Bagnall & Sons, Limited	3	2‡
14	Crookhay, "	H. O. Firmstone	4	0
15	Corbyn's Hall, Dudley	Wm. Matthews & Co., Limited	3	1§
16	Netherton, "	M. and W. Grazebrook	2	1
17	" "	J. H. Pearson	2	2
18	Parkhead, "	Phillips and McEwen	2	1
19	Woodside, "	Cochrane & Co.	2	2
20	Windmill End, "	Sir Horace St. Paul, Bart.	3	1
21	Buffery, "	John Jones & Son	1	1
22	Old Hill, "	N. Hingley & Sons	2	1
23	Corngreaves, "	The New British Iron Co.	6	2
24	Old Level, "	James Holcroft	2	0
25	New Level, Brierley Hill	Earl of Dudley	5	3
26	Coneygre, Dudley Port, Tipton	"	3	1
	Carried forward		74	29

* One furnace for ten months.
† One furnace for three months.
‡ One furnace for eight months.
§ One furnace for six months.

SOUTH STAFFORDSHIRE—*continued.*

No.	Name of Works.	Owners.	Furnaces.	
			Built.	In Blast.
			Nos.	Nos.
	Brought forward . .	. . . .	74	29
27	Lays, Dudley Port, Tipton .	W. and G. Firmstone . . .	3	1
28	Shut End, Dudley . . .	John Bradley & Co. . . .	4	1
29	Corbyn's Hall, New Dudley .	Bromley Coal and Iron Co.. .	4	0
30	Broadwaters, Wednesbury . .	Samuel Groucutt & Sons . .	3	1
31	Darlaston Steel and Iron, Wednesbury . . .	Darlaston Iron and Steel Co., Lim.	1	0
32	Priestfields, New, Willenhall .	William Ward & Sons . . .	2	0
33	Rough Hills, Wednesbury .	Addenbrook, Smith, & Pidcock .	3	1
34	Old Park, " . .	Patent Shaft and Axletree Co., Limited	3	0
35	Willingsworth, " . .	Willingsworth Iron Co. . . .	2	1
36	Moxley, " . . .	David Rose	2	0
37	Hatherton, Walsall . .	George and Richard Thomas . .	2	0
38	Pelsall, " . . .	Pelsall Coal and Iron Co. . .	2	1
39	Green Lane, " . . .	Walsall Iron Co.	2	1
40	Bentley, " . . .	Chillington Iron Co. . . .	2	0
41	Willenhall, " . . .	The Willenhall Furnaces, Lim. .	3	2*
42	Castle, " . . .	Castle Coal and Iron Co., Lim. .	2	0
43	Tipton Green, Tipton . .	Roberts & Co.	4	3
44	Hange (Tividale), " . . .	Round Brothers	2	1
45	Horseley, " . .	John Colbourn & Sons . .	4	1
46	Park Lane, " . . .			
47	Coseley Moor, " . .	Thos. Turley & Sons . . .	2	1
48	Wednesbury Oak, " . . .	Philip Williams & Sons . .	2	1
49	Groveland, Smethwick . .	G. H. Hickman	1	0
50	Brades Hall, ...	W. and E. Onions . . .	2	0
51	Park Lane	"	2	0
52	Union Valley	Stour Valley Coal and Iron Co., Limited	3	0
53	Stonefield	Thomas Crew	1	0
		Total of South Staffordshire	137	45

Malleable Iron Works:—Bessemer Steel Works, and Coal employed.—The malleable iron works of this district are by far the most numerous, and the manufacture the most varied, of the iron producing districts of Great Britain, including heavy iron works for railways, pit chains, cables, anchors, and the different forms of iron fashioned from the rolling and slitting mills. The great importance of the district will be understood from the annexed table, showing the number of works in South Staffordshire in each year since 1863, with their aggregate power of production, appearing in the number of puddling furnaces and rolling mills, in each of the years named; and for comparison the total number in Great Britain in each of the same years:—

* One furnace for four months.

Year.	South Staffordshire.			Great Britain.		
	Works.	Puddling Furnaces.	Rolling Mills.	Works.	Puddling Furnaces.	Rolling Mills.
	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.
1863	118	1,821	226	223	5,013	654
1865	118	2,116	224	252	6,407	730
1867	115	1,801	283	254	6,009	831
1869	110	1,700	282	245	6,243	859
1871	122	2,037	320	267	6,841	866
1872	125	2,155	329	276	7,311	1,015
1873	124	2,145	327	287	7,264	939
1874	123	2,073	320	298	6,803	866
1875	131	2,046	329	314	7,575	909
1876	129	2,009	342	312	7,159	942
1877	125	1,936	338	300	6,796	935
1878	127	1,684	303	312	5,125	830
1879	126	1,589	306	312	5,455	846
1880	125	1,625	311	314	5,134	855

The process of puddling may be briefly stated as consisting of the conversion of pig iron into malleable iron. This is effected by one or more operations, which are necessarily of an oxidising nature, the object being to eliminate from the cast iron the carbon in the form of carbonic oxide gas, and the silicon, sulphur, phosphorus, and other foreign bodies in the form of oxidised products, which pass either partially or wholly into the scoriæ or cinder. The pig iron is either subjected to a preliminary decarburisation in the oxidising blast hearth, or refinery, and the operation thus commenced afterwards completed in the oxidising air-furnace, or puddling furnace, or the complete conversion of the crude iron is effected by one operation in the puddling furnace by the process called "boiling." This process was first introduced in the Bloomfield Works of Mr. Joseph Hall, of Tipton, about the year 1811, and consists essentially in the decarburisation of the pig iron by contact with oxidised compounds of iron, whereby carbonic oxide is produced below the surface of the molten metal and in escaping causes the appearance of ebullition or boiling.

The Bessemer steel works of the district are represented by the Old Park Works at Wednesbury, consisting of four convertors, each of a capacity of three tons.

The following is a complete list of the works in South Staffordshire and East Worcestershire in the year 1880, with the number of puddling furnaces and rolling mills :—

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Brick House	R. Williams & Co.	West Bromwich	7	2
2	Bromford	Jno. Dawes & Sons	,,	63	7
3	Hall End	J. T. and W. E. Johnson	,,	9	2
4	Ridgacre	,, ,,	,,	15	2
5	Waterloo	,, ,,	,,	12	1
6	Crook Hay	W. and G. Firmstone	,,	18	2
7	Witton Lane	Roberts & Co.	,,	11	2
8	Excelsior	Thos. P. Allen & Co.	,,	9	1
9	Eagle	Eagle Coal and Iron Co.	,,	15	2
10	Staffordshire	Star Iron and Tin Plate Co.	,,	..	..
11	Providence	Bridge, Gill, & Bridge	,,	22	2
12	Roway	Edward Page & Sons	,,	20	3
13	Stour Valley	Patent Nut and Bolt Co., Limited	,,	10	1
14	Dunkirk	Thos. Jordan and P. Pearson	,,	9	3
15	Wellington	Allen & Holden	,,	11	2
16	Gold's Hill, New	Thomas Davis & Co.	,,	12	2
17	Bush Farm	John J. Bowater & Sons	,,	..	..
18	Richmond	Samuel Downing	,,	10	2
19	Albion	Edward Hall	,,	..	..
20	,,	Albion Sheet Iron Co.	,,	..	..
21	Britannia	Britannia Iron Co.	,,	10	1
22	Atlas	Parkes and Parkes	,,	10	3
23	Rabone Bridge	Rabone Bridge Iron Co.	Smethwick	..	..
24	Excelsior	South Staffordshire Joint Stock Co.	,,	7	1
25	Anchor	Batson and Ratcliffe	,,	6	1
26	District	District Iron and Steel Co.	,,	20	4
27	Cape Town	W. R. Brookes	,,	7	2
28	Crown	Thos. L. Nicklin	,,	11	3
29	London and Lion	London Works Iron Co.	,,	9	3
30	Vulcan	Parkes	,,	..	..
31	Regents Grove	Beard and Eberhard	,,	13	6
32	Sandwell	Lones, Vernon, & Holden	,,	16	3
33	Monmer Lane and Batman's Hill	Monmer Lane Iron Co.	Willenhall	24	8
34	Spring Bank	Catherine Tipper	,,	..	1
35	Dixon's Green	Frederick Cresswell	Dudley	11	1
36	Dudley Port	Plant and Fisher	,,	20	4
37	Groveland	G. H. Hickman	,,	..	..
38	Netherton	Noah Hingley & Sons	,,	41	4
39	Shut End	Jno. Bradley & Co.	,,	28	0
40	Globe	Tividale Iron Co.	Tipton	..	..
41	Tividale	,,	,,	..	..
42	Alpha	Joshua Wilkinson & Sons	,,	8	2
43	Bloomfield	Wm. Barrows & Sons	,,	58	8
44	Crown	Edward Bayley	,,	7	2
45	Church Lane	Hoddell and Whitehouse	,,	13	1
46	Albert	John Gittings & Co.	,,	10	2
47	Gospel Oak	Tipton Iron and Wire Co.	,,	..	..
48	Summer Hill	W. Millington & Co.	,,	5	4
49	Wednesbury Oak	Philip Williams & Sons	,,	22	5
50	Portfield	James and Chas. Holcroft	,,	13	4
51	Lea Brook	Chillington Iron Co., Lim.	,,	..	..
52	Brades (Iron and Steel)	Wm. Hunt & Sons	Oldbury	3	4
53	Ebenezer	Thomas Perry	,,	12	3
54	Park Lane	F. R. Simpson & Co.	,,	9	1
55	Great Bridge	Great Bridge Iron and Steel Co., Limited	Great Bridge	24	2
56	Sheep Wash	Stonehewer and Co.	,,	..	..
57	Gothersley	William Finnemore	Stourbridge	..	2
58	Bromley	John Raybould	,,	16	2
59	Broadwaters	Hatton, Sons, & Co.	,,	..	2
60	Leys	Brown and Freer	,,	27	7
61	Hyde	H. O. Fernestone	,,	32	7
62	Stourbridge	Jno. Bradley & Co.	,,	20	7
63	Whittington	James Williams & Co.	,,	..	..
64	Swindon	E. P. and W. Baldwin	,,	8	3
	Carried forward			773	149

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
	Brought forward	. . . . . .	. . . . .	773	149
65	Bank Field	S. Groucutt & Sons	Bilston	21	4
66	Bradley Field	,, ,,	,,	23	4
67	Bilston Mill and Forge	W. & J. S. Sparrow & Co.	,,	26	3
68	Bradley Tin Plate	Hatton, Sons, & Co.	,,	6	4
69	Bradley, New	Gitting and Tolley	,,	11	1
70	Deepfields	Geo. Tinn & Co.	,,	20	7
71	Bridge	David Jones & Sons	,,	..	..
72	Herbert's Park	,, ,,	,,	..	..
73	Regent	George Onions	,,	9	3
74	Stonefield	Bilston Iron Co.	,,	18	5
75	Factory	,,	,,		
76	Ettingshall	The Barbor's Field Co.	,,	..	..
77	Moxley	Thos. and Chas. Wells	,,	..	..
78	Bradley Hall	J. E. East & Co.	,,	3	1
79	Capponfield	Chillington Iron Co., Lim.	,,	..	..
80	Brockmoor	Budd & Co.	Brierley Hill	2	6
81	Delph	Delph Forge and Rolling Mills Co.	,,	..	..
82	Harts Hills	Hingleys and Smith	,,	34	4
83	Round Oak	Earl of Dudley	,,	55	5
84	New Level	,,	,,		
85	Brettle Lane	Thos. Webb & Sons	,,	10	2
86	Brockmoor	Jno. Bradley & Co.	,,	..	..
87	Brierley	,, ,,	,,	10	3
88	Corngreaves	New British Iron Co.	,,	60	8
89	Providence	Joseph Penn & Co.	,,	7	1
90	Old Level	Henry Hall	,,	16	2
91	Cradley	S. Evers & Sons	,,	16	3
92	Monmoor	E. T. Wright & Sons	Wolverhampton	25	6
93	Mars	Geo. Adams & Sons	,,	25	5
94	Minera Iron and Steel	Isaac Jenks & Sons	,,	12	3
95	Beaver	,, ,,	,,	7	3
96	Swan Gardens	John Lysaght	,,	24	7
97	Horseley Fields	Osier Bed Iron Co.	,,	12	3
98	Chillington	Chillington Iron Co., Lim.	,,	62	12
99	Horseley Fields	E. P. and W. Baldwin	,,	3	1
100	Cleveland	Cleveland Iron Co.	,,	10	1
101	Manor	Stephen Thomson	,,	10	2
102	Birchills	James Bissell	Walsall	13	1
103	Birchills Hall	Birchills Hall Iron Co., Limited	,,	12	4
104	Staffordshire	Bunch & Sons	,,	12	6
105	Pelsall	Pelsall Coal and Iron Co., Limited	,,	42	6
106	Victoria (Pleck)	Henry Mills & Sons	,,	6	1
107	Cyclops	John Russell & Co., Limited	,,	17	2
108	Cormorant	Harrison, Hopkins, & Harrison	,,	11	2
109	Churchbridge	W. Gilpin, sen., & Co.	,,	8	2
110	Darlaston Green	Darlaston Coal and Iron Co., Limited	Darlaston	..	..
111	King's Hill	,, ,,	,,	..	..
112	Old Park	Patent Shaft and Axletree Co., Limited	Wednesbury	38	4
113	Monway Iron and Steel	,, ,,	,,		
114	Brunswick	,, ,,	,,		
115	Bull's Bridge	W. Molinenx & Co.	,,	48	5
116	Monway	John Marshall & Co.	,,	7	2
117	Bull's Bridge	Southan, Bradley, & Co.	,,	5	2
118	Victoria	David Rose	,,	10	3
119	Toll End	Jno. Bagnall & Sons, Lim.	Tipton	66	7
120	Lea Brook	,, ,,	,,		
121	Gold's Hill	,, ,,	West Bromwich		
122	Imperial	,, ,,	Wednesbury		
123	Hinksford	T. and G. Hall	King's Winford	..	..
124	Cookley	Jno. Knight & Co.	Kidderminster	16	4
125	Wilden	E. P. and W. Baldwin	Stourport	5	5
	Total of South Staffordshire and Worcestershire			1625	311

Coal used in Malleable Iron Works.—In considering the question of the consumption of coal in the malleable iron and steel works of this district, although great care has been taken to ascertain the quantities used, it is only possible to arrive at an approximate result. It may, however, be generally stated that the average quantity of coal used annually in a puddling furnace in this district, working regularly throughout the year, (deduced from numerous returns,) varies between 800 and 900 tons, or an aggregate annual consumption of not less than 1,600,000 tons in 1863, increased to nearly 2,000,000 tons from 1871 to 1876, and a diminished consumption since that period. These quantities include fuel used in the tin-plate works, as well as the fuel employed for all purposes where heat is required. The total coal employed in these works in 1879 was 1,567,600 tons, and in 1880 it amounted to 1,656,953 tons.

Prices of Finished Iron.—It is scarcely necessary to describe the general qualities of Staffordshire iron. These are well known to every one engaged in the iron trade. Forty years ago an eminent authority, in writing on the characteristic differences between the cast iron made in different parts of Great Britain, observed that "the Staffordshire metal runs remarkably fluid and makes fine sharp castings. The Welsh is strong, less fluent, but is said to produce bar iron of superior quality. The Derbyshire iron also forms excellent castings, and may be worked with care into very good bar iron. The cast iron produced in Staffordshire and Shropshire generally commands a higher price than the irons of other districts, except some of the best brands of the West Riding of Yorkshire."

The highest price ever attained in South Staffordshire for finished iron was £16 a ton, a price which it commanded in the summer of 1872. Its lowest point was £7 10*s*., which it stood at for barely two months in 1879, and which it has again touched. It has also previously approached the latter figure. In 1863 and two previous years its average price was £7 15*s*., and again in 1868—69 it sold at that price. Till 1872 what might be termed its normal price was between £8 and £9 a ton. The average price of Welsh bars, excepting the years 1872 and 1873, has been from £5 5*s*. to £6 6*s*. a ton. The greatest variation in prices took place during the last ten years, as appears from the following account of them for that period :—

PRICES OF SOUTH STAFFORDSHIRE MARKED IRON.

Date.	Rise or Fall.	Price per Ton.	Number of Weeks Duration.
	s.	£ s.	
January 1, 1871	...	8 0	35
September 7, 1871 . . .	Rise 10	8 10	25
October 15, 1871 . . .	,, 10	9 0	5
January 1, 1872	,, 40	11 0	5
February 3, 1872 . . .	,, 20	12 0	10
April 11, 1872	,, 10	12 10	3
May 16, 1872	,, 10	13 0	5
June 20, 1872	,, 20	14 0	1
June 27, 1872	,, 20	15 0	2
July 11, 1872	,, 20	16 0	12
October 3, 1872 . . .	Fall 40	14 0	4
October 31, 1872. . . .	,, 40	12 0	11
January 16, 1873 . . .	Rise 20	13 0	4
February 13, 1873 . . .	,, 20	14 0	4
March 13, 1873 . . .	,, 40	16 0	16
July 3, 1873	Fall 40	14 0	52
July 8, 1874	,, 40	12 0	13
October 7, 1874	,, 20	11 0	38
July 7, 1875	,, 20	10 0	42
April 26, 1876	,, 20	9 0	71
September 7, 1877 . . .	,, 10	8 10	54
September 17, 1878 . . .	,, 20	7 10	7
November 6, 1879 . . .	Rise 10	8 0	7
December 31, 1879 . . .	,, 20	9 0	13
April 30, 1880	Fall 20	8 0	22
October 6, 1880	,, 10	7 10	still current.

This account of the market value of the finished iron of South Staffordshire indicates that it is used for special purposes. These purposes are almost innumerable. It has hitherto been regarded as an indispensable material for making the best quality of goods. There is scarcely any description of finished iron, excepting, of course, mild steel, that is not produced in South Staffordshire; from boiler-plates and rails, down to the most delicate and fanciful wares to be found in the ironmonger's shop. Of late years mild steel has come into competition with it for the heavier class of goods produced there, such as rails, boilers, girders, &c. But for many other purposes Staffordshire pig is still indispensable, such as ironmongery, chains, tin plates, gun barrels, nails, and similar articles.*

* *Colliery Guardian*, March 4, 1881, p. 331.

CHAPTER XII.

NORTHAMPTONSHIRE IRON INDUSTRIES.

Geology of the Ironstone Deposits of the Northampton Sand—Analyses, Production, and Distribution of Ironstone—Iron Mines in 1880—Pig Iron Manufacture—Early History—Direct Process (Dr. C. W. Siemens' Patent) for making Iron and Steel at Towcester—Iron Works in operation in 1880—Production of Pig Iron—Coal and Ironstone used in Pig Iron Manufacture.

Northamptonshire Ironstone Deposits.—The "Northampton sand," a subdivision of the Lower Oolitic formation, in which those vast deposits of ironstone occur, reposes upon the Upper Lias Clay, and is composed of ferruginous sands, sandstones, and in some places assumes a concretionary character, in the form of a thin coating of ironstone, inclosing loose sand. In the neighbourhood of the iron-bearing districts the following table shows the superposition, in descending order, of the strata :—

Alluvium.
Gravel of the New and Ise Valleys.
Oxford Clay.
Cornbrash (Blue Limestone and clay).
Great Oolite (White Limestone and clay).
Northampton Sands (Iron Sand and Sandstones, the equivalent of the Stonesfield Slate).
Upper Lias Clay.

In the Upper Lias Clay there are numerous brick yards, in which brick-making is extensively carried on; lower in the geological series occurs the "Marlstone," or "Middle Lias," and the Lower Lias Clay below; while above the Northampton sand in the southern part of the county occurs the Great Oolite, consisting of light coloured limestones and clays, and higher still the Cornbrash and Oxford Clay. The beds of ironstone vary in thickness from 4 to 18 feet and even more, and with an equally varying "over-burden," in some localities but a few feet; while at Cogenhoe and Woodford, the former a few miles from Northampton on the line to Peterborough, and the latter between

Thrapston and Kettering, it exceeds 20 feet, and in these places the stone was formerly mined by underground workings. At Cogenhoe the bed of ironstone is well defined, and has a thickness of 5 feet, the over-burden being composed of a loose reddish earth, associated with sand, in which fossils occur in abundance to a depth of 14 feet, and beneath this is a stratum of pure white sand (at times coloured with peroxide of iron), and having the appearance of chalk; the ironstone bed below has a slight dip to the north-east. The stone here obtained is very compact, and gives on analysis 42 per cent of metallic iron. At Gayton, to the west of Northampton, near Blisworth, the ironstone is from 10 to 14 feet thick, the over-burden being but a few feet, while at Easton Neston, near Towcester, it varies from 6 inches to 3 feet. Near Northampton, at Hunsbury Hill, the ironstone attains a thickness of from 12 to 14 feet, and with a covering of 5 feet, consisting of soil 2 feet, and 3 feet of fine white sand and marl below. In the north of the county and on the borders of Leicestershire, the bed of ironstone is well defined, extending for several miles along the Midland Railway to Finedon, and thence to Wellingborough, and as far as Blisworth and Gayton, and on to the town of Northampton. At Duston, near Northampton, stone is found fully 16 feet thick, and this is exceeded on some estates as previously stated, notably those at Woodford of Mr. Arbuthnot, and at Cranford, on the estate of Sir John Robinson, bart.; again, at Islip, between the last-named place and Thrapston. At Islip the ironstone is extensively wrought and smelted in the furnaces of the same name; the ironstone obtained in these districts is of very good quality. In other localities the stone is not so rich, it also varies considerably in weight, according to the richness, density, or other general character of the stone. A cubic yard of ironstone in "*situ*" with shale and adhering rock will weigh about 24 cwts.; but to weigh that it must be clean, and entirely free from sand walls, dirt, &c. It will therefore be apparent that ironstone varying so much in thickness and containing numerous "faults," such as walls of sand and clay, that the actual yield or weight of the stone as it lies, cannot be accurately determined. Near the Midland Railway at Wellingborough, where the ironstone has been vigorously worked by the Messrs. Butlin & Co., it appears that one field of 9 acres, in which the thickness of the

bed of ironstone varied from 12 feet, 6 feet of which was solid rock, the remainder containing a good deal of "siftings" gave 98,286 tons of ironstone, an average of nearly 11,000 tons per acre, but some parts of the same field gave over 12,000 tons per acre. These facts will, so far as the ironstone is concerned, show conclusively its value in some districts, and its production per acre as well. The great seam of ironstone in Cleveland, be it remembered, yields 20,000 tons per acre. In another field, worked by the same firm at Wellingborough, the ironstone is from 15 to 16 feet thick, and some varieties of stone from this seam selected for analysis have given nearly 50 per cent. of metallic iron. The stone is worked from the surface as a quarry, and an interesting matter connected with the working of the ironstone at Wellingborough, is, as soon as it is got the land is made good again, and fit for agricultural purpose. In one tract of ground, now in a state of cultivation, no less than 200,000 tons of ironstone was obtained, and yet its appearance would not suggest that it had been disturbed. For the transport of the stone ample facilities are provided, trucks bringing coals to the iron works are quickly unloaded, and as quickly charged with ironstone at the mines or quarries, and moved on to the railway siding for exportation or otherwise.

Seeing that many of the old districts on which dependence was formerly placed for the supply of iron ore are gradually being exhausted, Northamptonshire is evidently destined to become an important iron-making centre. This appears in the increased activity from year to year, and the production, which in 1880 amounted to 1,550,103 tons, compared with 107,985 tons in the year 1857.

Analyses of the Ironstone.—The ironstone raised at Heyford and Wellingborough, and examined at the Royal Arsenal at Woolwich,* are thus described:—Heyford ore: "Ochrey brown ironstone, hydrated peroxide of iron from the same district, and similar in general character to the ore from Wellingborough. The sample analysed was an average of the two specimens received." The Wellingborough ore: "Three samples of the ochrey brown ironstone of the district were forwarded. They were of various degrees of hardness and density, though all consisted principally

* "Cast Iron Experiments," Parliamentary Return, No. 497, June, 1858.

of hydrated peroxide of iron. An average sample was prepared for the purpose of analysis." The results are thus tabulated :—

Constituents.	Heyford.	Wellingborough.
Peroxide of iron	56·20	76·00
Protoxide of iron . . .	trace.	trace.
Oxide of manganese . .	0·20	0·40
Alumina	2·43	2·30
Carbonate of lime . . .	0·49	0·41
Carbonate of magnesia . .	0·17	0·11
Phosphoric acid . . .	0·84	1·03
Water hygroscopic . . .	1·16	1·80
Water in combination . .	9·74	12·40
Insoluble residue . . .	29·07	5·33
	100·30	99·78
Metallic iron	39·34	53·20

In neither ore does there appear to have been any appreciable amount of sulphur discovered, the insoluble residue in the Weedon ore consisting of quartz, soluble silica, and a little mica, and the Wellingborough silica almost entirely, with a trace of mica.

The Wellingborough ore raised by the Messrs. Butlin, Bevan, & Co., and smelted at the East-end and Irthlingborough Iron Works (the former long since dismantled), has been examined in Dr. Percy's laboratory in the Royal School of Mines, and is thus described :—"The ore consists essentially of earthy hydrated sesquioxide of iron. It is oolitic in structure, and ochre-brown in colour, the insoluble residue consisted almost entirely of silicious oolitic concretion, but on dissolving these in potash a small amount of residue was left, containing a quartzose sand, scales of mica, and minute spherical particles of magnetic oxide of iron. The ore contains numerous marine shells, and occurs in the Northampton sand, which lies at the base of the Great Oolite, and is the geological equivalent of the Stonesfield slate. A trace of copper was detected in 600 grains of the ore."

Other ores from the neighbourhood of Wellingborough show the following chemical constituents. The first analysis was made by Mr. John Spiller, the second and third by Mr. Edward Riley, and yield respectively of metallic iron 37·00 per cent., 24·09 per cent., and 35·37 per cent. The amount of phosphoric acid contained in each ore being respectively 1·26 per cent., 1·47 per cent., and 1·28 per cent. :—

RESULTS TABULATED.

Constituents.	First.	Second.	Third.
Sesquioxide of iron	52·20	34·41	50·31
Protoxide of iron	trace.	trace.	trace.
Protoxide of manganese	0·51	0·27	0·51
Alumina	7·13	6·19	7·25
Lime	7·13	25·68	11·76
Magnesia	0·57	0·85	0·62
Silica	1·60	0·89	0·22
Carbonic acid	4·92	18·45	7·98
Phosphoric acid	1·26	1·47	1·28
Sulphuric acid	...	0·07	...
Bisulphide of iron	0·03	0·30	0·17
Water hygroscopic and combined	11·37	6·97	11·00
Ignited insoluble matter	13·55	5·82	9·33
	100·27	101·37	100·43
INSOLUBLE RESIDUE.			
Silica	11·56	5·80	8·58
Alumina	0·26	0·21	0·27
Sesquioxide of iron	0·66		0·22
Lime	0·33	0·04	0·16
Magnesia	0·11	0·02	trace.
Potash	...	...	0·11
	12·92	6·07	9·34
Metallic iron	37·00	24·09	35·37

The prevailing mineral characters of the clays and sands of the formation containing the ferruginous beds are very fully described by Prof. J. W. Judd,* in his memoir, "The Geology of Rutland, &c.," in which work an interesting chapter appears, "On the Conditions under which the Northampton Sand was deposited."

Other samples † of these ironstones, examined by Mr. A. Dick, consisting of an inner and outer portion respectively of a lump of Northamptonshire ore, are thus described, and give the following results:—

"The inner portion, it will be observed, consists for the most part of carbonate of protoxide of iron, and the outer portion of hydrated sesquioxide, the latter having been clearly derived from the former by atmospheric action:—

* "Geology of Rutland," p. 128.

† Percy's "Metallurgy of Iron and Steel," p. 209.

RESULTS TABULATED.

Constituents.	Inner Portion.	Outer Portion.
Sesquioxide of iron	...	38·04
Protoxide of iron	33·29	10·54
Protoxide of manganese	1·11	0·69
Alumina	4·62	12·35
Lime	0·50	trace.
Magnesia	7·96	4·13
Potash	...	...
Silica	1·99	1·96
Carbonic acid	24·79	0·16
Phosphoric acid	0·22	0·26
Sulphuric acid	trace.	trace.
Bisulphide of iron	0·13	0·13
Water combined	0·54	6·92
Organic matter	0·08	0·19
Ignited insoluble residue	24·09	24·61
	99·32	99·98
INSOLUBLE RESIDUE.		
Silica	17·50	21·28
Alumina	3·27	2·67
Sesquioxide of iron	3·31	...
Lime	trace.	trace.
Magnesia	0·81	0·22
Potash	0·20	0·38
	25·09	24·55
Metallic iron	28·28	34·83

It is further remarked that no metal precipitated by sulphuretted hydrogen was detected in a solution of 880 grains of the ore of the inner portion. On the contrary, extremely minute traces of copper and lead were detected in a solution of 744 grains of the ore of the outer portion, so that these metals appear to have been communicated to the ore by water from without.

The ironstone worked in the neighbourhood of Blisworth, where the deposit attains considerable thickness, shows the following constituents; the samples submitted for examination were selected from unweathered portions of the bed, from the upper and lower parts, and the analysis made by the late Mr. David Forbes, F.R.S. An average sample of the stone worked at Blisworth by Messrs. Bevan & Co. shows the results stated; the stone yielding 40 per cent. of metallic iron.

Constituents.	Lower Portion.	Upper Portion.	Blisworth Stone.
Protoxide of iron	40·93	49·58	57·79
Sesquioxide of iron . . .	6·14	5·67	...
Bisulphide of manganese . .	...	0·96	...
Protoxide of iron . . .	0·16	0·16	0·70
Alumina	8·08	1·56	2·03
Lime	3·47	3·24	0·40
Magnesia	2·21	0·46	0·52
Carbonic acid	22·32	34·64	...
Phosphoric acid	1·99	0·44	1·20
Potash	0·19	...	...
Soda	0·27	...	...
Sulphur	trace.	...	trace.
Silica	9·04	2·16	11·40
Organic matter	...	trace.	...
Water	4·92	1·56	...
Loss by calcination . . .	...	...	26·02
Total . .	99·72	100·43	100·06

The specific gravity at 60° Fahr. was found to be 3·401; and an examination by the microscope showed it to consist almost entirely of two mineral constituents, the one crystalline and colourless, being chiefly carbonate of iron, and the other of a green colour, probably silicate of alumina and iron. Whether the green colour is due to it or the presence of phosphate of iron is not decided, but it appears probable that a green silicate does exist in the mineral.

The ironstone raised at Brixworth and Thrapston, the former examined by Dr. Noad, F.R.S., the latter by Dr. Percy, F.R.S., show the following constituents. The ore was dried by exposure in a finely pounded state in the air of the private room of the laboratory.

Constituents.	Brixworth.	Thrapston.
Peroxide of iron	64·20	64·72
Silica	14·80	11·40
Magnesia	1·72	0·53
Alumina	...	3·49
Lime	...	3·96
Phosphoric acid	0·892	2·06
Sulphur	...	0·07
Oxide of manganese	2·80	...
Loss by calcination	...	15·16
Water	15·40	...
Total . .	99·812	101·39

The material selected for the analysis of the Brixworth stone was obtained from the cutting of a vertical groove in the face of the rock, extending from the top to the entire depth. The yield of metallic iron from this stone was 43·93 per cent., the Thrapston ore giving 45·31 per cent.

The ironstone in the neighbourhood of Easton Neston, near Towcester,—where the bed has an average thickness of 6 feet, dipping slightly to the east,—is described as hard and compact, and has been found very suitable for reduction by the Siemens process. Several analyses of this ore made in the laboratory of the Towcester Iron Ore Co. give the following results. The analyses were made by Mr. H. Le Neve Foster, the last sample of ore (No. 5) being previously calcined:—

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Peroxide of iron . .	54·10	50·70	52·04	51·00	66·60
Protoxide of iron . .	trace.	trace.	trace.	2·00	...
Protoxide of manganese.	trace.	0·11	2·23	0·20	trace.
Lime	...	...	...	1·70	...
Alumina	12·70	14·10	8·76	10·00	15·13
Silica	12·30	15·30	16·30	14·00	11·90
Phosphoric acid . .	2·15	2·10	·24	1·50	1·37
Sulphur	trace.	trace.	0·33	trace.	·62
Carbonic acid and water	19·80	16·30	19·50	19·60	3·50
Total . .	101·05	98·61	99·40	100·00	99·12
Metallic iron . . .	37·90	35·50	37·43	37·20	46·67

The ironstone in the southern part of the county near Culworth, worked but to a limited extent, gives the following results on analysis:—

RESULTS TABULATED.

Peroxide of iron	60·89
Lime	1·12
Alumina	2·80
Magnesia	trace.
Phosphoric acid	1·27
Sulphuric acid	trace.
Sand and silicate	19.96
Moisture and combined water	13·04
Loss, &c.	0·92
Total	100·00

The equivalent of metallic iron contained in the above peroxide was 42·62 per cent., other analyses of the same stone, made at Birmingham, gave 44·16 per cent.; at Oxford, 43·07 per cent.; and in London, 42·80 per cent., showing an average of 43 per cent.

The ore raised by the Cogenhoe Iron Ore Company gives from 43 to 48·50 per cent. of metallic iron, the latter, of which the annexed is an analysis, giving in the calcined state 55·25 of metallic iron:—*

RESULTS TABULATED.—ORE DRIED AT 212° FAHR.

Peroxide of iron	69·29
Oxide of manganese	1·02
Alumina	3·08
Lime	1·65
Magnesia	1·08
Sulphur	0.07
Phosphoric acid	0·53
Sulphuric acid	0·43
Silicious matter	10·80
Combined water	12·03
Total	99·97

The following analysis, by Dr. Voelcker, F.R.S., of a friable portion of the Northamptonshire iron ore, obtained from a locality situated near Blisworth, shows a great reduction in the quantity of iron, and a considerable increase in the earthy constituents:—

RESULTS TABULATED.†

Protoxide of iron	0·875
Sesquioxide of iron	21·280
Phosphoric acid	1·030
Sulphuric acid	0·219
Silica, lime, alumina, magnesia, &c., not separately determined	76·596
Total	100·000

In the following appears a summary of the amount of metallic iron contained in the ironstone of the mines named, and in each case where known the name of the analyst is given:—

* The Author was favoured with this analysis by Mr. M. C. Cohen, of the Cogenhoe Iron Ore Company, who is also working the iron ore deposits at Caythorpe in Lincolnshire.

† 'Geology of Rutland," p. 127.

Mine.	Analyst.	Metallic Iron.
Blisworth	Dr. Percy	40·00
,, ...	Mr. Harris . . .	40·00
Brixworth . . .	Dr. Noad	43·93
Culworth . . .	... .	43·00
Duston	... .	40·00
Burton Latimer . .	... .	35·00
Cogenhoe	... .	43·00
,, ...	... .	48·50
Desborough . . .	... .	38·00
,, ...	Dr. Percy . . .	36·79
Gayton	... .	42·00
Heyford . . .	Mr. Judkins . . .	39·34
Hardingstone . . .	Mr. A. Dick . . .	52·05
Northamptonshire Ore*.	,, ...	28·28
,, ,, .	,, ...	34·83
Thrapston . . .	Dr. Percy	36·79
Weedon	Woolwich Arsenal . .	39·34
Wellingborough . .	,, ,, . . .	53·20
,, . . .	Mr. John Spiller . .	37·00
,, . . .	Mr. Edw. Riley . .	35·37
Woodford	Dr. Percy	44·00
Towcester . . .	Mr. H. Le Neve Foster.	37·90
,, ...	,, ,, . .	35·50
,, ...	,, ,, .	37·43
,, ...	,, ,, . .	37·20
,, ...	,, ,, .	46·67

Production and Distribution of Ironstone.—Dr. Percy relates the following incident showing the circumstances under which the working of the ironstone deposits of the Northampton sand was resumed in modern times:—"The introduction of the Northamptonshire ore is only of recent date. Not long previous to the International Exhibition of 1851, Colonel (now General) Arbuthnot called upon me in Birmingham, where I then resided, and requested my opinion on the specimen of the ore which he left with me. I found it to contain a sensible quantity of sesquioxide of iron and a very large amount of silicious sand. I made no quantitative examination of it; and certainly the specimen in question did not prepossess me in its favour. However, I referred the Colonel to my friend, Mr. S. H. Blackwell, of Dudley, who visited the locality of the ore in order to examine it *in situ*. He obtained samples much richer in iron than that which was placed in my hands. He prosecuted inquiries on the subject with his usual energy, and the result has been the discovery of an

* Locality not stated.

extensive deposit of ore, which has since been smelted in large quantities in South Staffordshire, Derbyshire, and South Wales."*

The deposits in the neighbourhood of Blisworth and Weedon in the year 1855 produced 74,084 tons, increased to 91,592 tons in the year 1856; of this quantity 1,592 tons was sent out of the district by canal, and 90,000 tons by rail. Again, in the year 1857 the yield increased to 107,985 tons; of this quantity 29,550 tons were smelted in the iron works of the county, the remainder being distributed by the London and North-Western and Midland Railways; since that date the output of the mines of Northamptonshire has been as follows:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1857	107,985	1869	540,259
1858	140,485	1870	887,020
1859	130,098	1871	914,435
1860	95,664	1872	1,174,211
1861	113,129	1873	1,412,255
1862	116,718	1874	1,056,478
1863	126,578	1875	1,085,898
1864	335,787	1876	1,161,130
1865	364,349	1877	1,049,806
1866	476,981	1878	1,189,443
1867	416,765	1879	1,211,406
1868	449,116	1880	1,550,103

The ironstone is widely distributed, its silicious character rendering it useful as an admixture with the argillaceous ores of the coal measures. The great bulk is sent away to South Wales, Derbyshire, and South Staffordshire, bearing a carriage-rate by railway of from 2*s*. 6*d*. to 7*s*. 6*d*. according to distance. Like the ironstone of North Lincolnshire it is easily wrought, and is put into railway waggons at the mines at prices varying from 2*s*. 6*d*. to 4*s*. per ton, according to quality. The Midland Railway carried ironstone out of the county as follows in each of the years:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1869	319,696	1875	774,560
1870	397,903	1876	775,700
1871	535,099	1877	862,468
1872	681,798	1878	898,384
1873	845,763	1879	846,352
1874	793,048	1880	1,009,143

* Percy's "Metallurgy of Iron and Steel," p. 225.

The destination of the ore thus distributed does not here appear; however, the following figures show the quantities carried by the Midland Railway from their respective stations in each of the later years given below:—

Stations.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.
Desborough . . .	91,948	119,527	103,220	104,186
Rushton	101,325	116,153	138,677	123,498
Grunston	...	...	17,365	117,107
Kettering . . .	1,265	33,793	69,879	39,879
Melton	...	54,826	61,266	...
Cranford . . .	43,682	53,955	58,981	90,243
Twywell	169,970	143,034	105,451	125,385
Thrapston . . .	13,400	19,709	14,623	14,078
Isham	6,914	2,915	143	103
Wellingborough . .	406,005	336,604	258,462	376,520
Irchester	27,959	17,868	18,285	18,144
Total . .	862,468	898,384	846,352	1,009,143

In the annexed table appears the quantities of ironstone raised from a few of the more extensive workings in the county, which will generally show how largely the ironstone is wrought in the neighbourhood of Blisworth by the Messrs. G. E. Bevan & Co., and others:—

Year.	Blisworth.	Gayton.	Duston.	Towcester.
	Tons.	Tons.	Tons.	Tons.
1870	59,424	74,866	45,330	...
1871	64,354	51,578	52,713	...
1872	83,514	33,961	150,722	...
1873	81,107	76,675	180,934	7,953
1874	72,672	22,823	93,907	6,000
1875	39,534	51,677	53,983	43,571
1876	25,559	68,417	54,550	57,684
1877	20,258	72,940	50,136	35,800
1878	16,114	63,865	13,492	12,719
1879	12,868	65,608	18,024	16,499
1880	52,350	73,350	95,540	51,050

The ironstone raised at Blisworth, Gayton, and Duston, is sent away in considerable quantities by canal and railway to the Midland iron districts and to South Wales.

The mines in the neighbourhood of Wellingborough worked by Messrs. Butlin, Bevan & Co., have yielded ironstone in the following quantities in each of the years named:—

Year.	Wellingborough.	Ringstead.	Irchester.	Dean and Chapter Lands.	Wollaston.
	Tons.	Tons.	Tons.	Tons.	Tons.
1870	180,127	...	...	*	...
1871	152,585	...	...	89,266	...
1872	65,914	43,498	46,961	114,868	...
1873	175,263	60,058	100,532	87,504	...
1874	118,579	19,641	81,721	80,538	...
1875	87,380	22,461	47,749	58,945	66,460
1876	127,324	11,040	33,915	67,487	73,681
1877	111,620	10,839	28,062	32,776	84,468
1878	65,633	14,454	17,999	26,906	110,931
1879	37,945	5,398	17,329	3,539	68,907
1880	67,482	21,326	16,684	†	112,555

Considerable quantities of ironstone are raised in the neighbourhood of Wellingborough, beyond the above, by the Stanton Ironworks Co., who also work stone at Desborough, given below. The Newbridge Iron Co. at Newbridge and Ringstead have for some years produced stone as follows :—

Year.	STANTON IRON WORKS CO.		NEWBRIDGE IRON CO.	
	Wellingborough.	Desborough.	Newbridge.	Ringstead.
	Tons.	Tons.	Tons.	Tons.
1870	5,175	104,060	...	...
1871	...	113,370	52,450	...
1872	‡149,953	127,427	70,000	43,498
1873	...	150,000	108,535	§
1874	...	150,000	...	...
1875	93,362	90,439	56,157	24,178
1876	113,538	71,824	54,335	22,246
1877	112,000	62,700	60,430	17,289
1878	110,000	79,000	59,490	17,688
1879	101,350	68,459	69,494	11,640
1880	101,070	66,167	77,699	21,326

The other mines to refer to are those lying between Thrapston, Kettering, and Finedon, where the Glendon Iron Ore Co. are large raisers of ironstone, principally consumed in their own furnaces. The table below gives the quantities raised in the mines named, the Glendon return including stone raised at Finedon and Burton Latimer :—

* Included in Wellingborough. † Worked out.
‡ Including Ironstone raised from other works in the district of Wellingborough.
§ Included in Newbridge.

Year.	Islip.	Woodford.	Cranford.	Glendon Iron Co.
	Tons.	Tons.	Tons.	Tons.
1870	25,000	129,913	21,712	95,964
1871	60,771	64,281	19,549	96,910
1872	35,700	73,502	21,920	98,148
1873	37,500	79,898	21,585	118,328
1874	35,000	69,735	20,786	96,264
1875	63,833	54,580	27,897	81,828
1876	65,000	58,359	27,000	100,000
1877	50,000	57,371	30,000	125,000
1878	50,000	50,000	40,000	130,000
1879	81,495	...	56,091	160,000
1880	77,666	...	89,671	159,100

The mines in operation in 1880 were as follows, producing 1,550,103 tons, of the value of £231,359, and exceeding the output of the previous year by 338,697 tons :—

No.	District or Mine.	Character of Ore.	Quantities.		Value.		
			Tons.	Cwts.	£	s.	d.
1	Blisworth (Bevan & Co.) . .	Hydrated oxide	52,350	0	7,852	10	0
2	Brixworth	"	28,621	0	3,577	7	6
3	Cranford	"	89,671	0	11,209	0	0
4	Cransley	"	105,780	0	14,547	0	0
5	Desborough (Stanton Iron Works Co.) .	"	66,167	0	9,097	19	3
6	" (F. V. Smith) . .	"	18,725	0	3,276	0	0
7	" (W. C. Wheldon) .	"	18,000	0	2,500	0	0
8	Ditchford (Butlin, Bevan, & Co.)	"	38,532	0	5,298	3	0
9	Duston	"	95,540	10	11,942	5	0
10	Easton Neston	"	61,050	0	7,657	10	0
11	Finedon Road Bridge . . .	"	89,167	0	13,375	0	0
12	Finedon (Glendon Iron Co.) .	"	20,000	0	4,000	0	0
13	Burton Latimer	"	9,500	0	1,900	0	0
14	Glendon "	"	129,600	0	25,920	0	0
15	Gayton (H. W. Wheldon) . .	"	19,262	0	2,939	0	0
16	Gayton (Heyford Iron Co.) . .	"	54,088	0	9,465	8	0
17	Irchester (Butlin, Bevan, & Co.) .	"	16,684	0	2,294	1	0
18	Islip	"	77,666	0	15,533	4	0
19	Hunsbury Hill	"	18,849	0	2,356	2	6
20	Newbridge	"	77,699	0	9,712	7	6
21	Ringstead (Newbridge Iron Co.)	"	13,512	0	1,857	18	0
22	Ringstead (Butlin, Bevan, & Co.)	"	21,326	0	2,932	6	0
23	Spratton	"	46,420	0	5,802	10	0
24	Thrapston	"	14,240	0	1,780	0	0
25	Wellingboro' (Butlin, Bevan, & Co.	"	67,482	0	9,278	15	0
26	Wellingboro' (Stanton Iron Works Co.)	"	101,070	0	15,160	0	0
27	Wollaston (Butlin, Bevan, & Co.)	"	112,555	0	15,476	0	0
28	Warren Hill	"	47,547	0	7,118	11	0
29	Sundry Pits	"	50,000	0	7,500	0	0
	Total of Northamptonshire .	. . . .	1,550,103	10	231,358	17	9

The iron mines of Northamptonshire, their situation, proprietors and chief agents, are contained in the annexed list at the present time (1881):—

No.	Name of Mine.	Situation.	Name of Proprietor or Company.	Name of Manager or Agent.
1	Blisworth . .	Blisworth . .	G. E. Bevan and Co., Lim.	Richard P. Jones.
2	Brixworth . .	Brixworth . .	Attenborough and Co. . .	Richard Timms.
3	Burton Latimer.	Kettering . .	Glendon Iron Co. . .	George E. Checkland. J. P. Cramp.
4	Cranford . .	" . .	Staveley Coal and Iron Co., Limited	George Bond. Henry Westlake, Sec.
5	Cransley . .	" . .	Cransley Iron Co., Limited	John Wallis.
6	Cogenhoe . .	Northampton .	Cogenhoe Iron Ore Co. . .	M. C. Cohen.
7	Desborough .	Market Harborough .	Stanton Iron Works Co.; G. Crompton, Managing Director . . .	John Hickman.
8	" . .	" . .	W. C. Wheldon . . .	W. C. Wheldon.
9	" . .	" . .	F. V. Smith	F. V. Smith.
10	Ditchford . .	Irthlingborough.	Butlin, Bevan, & Co. .	Lewis W. Perrin.
11	Duston . .	Northampton .	Henry Higgins . . .	James Saunders.
12	Easton Neston .	Towcester .	Easton Estate and Mining Co., Limited . .	Sydney J. Bates.
13	Finedon . .	Kettering . .	Glendon Iron Co. . . .	George E. Checkland.
14	Finedon Road Bridge .	Finedon . .	Rixon & Co. . . .	James Rixon.
15	Gayton . .	Blisworth . .	Henry W. Wheldon . .	Henry W. Wheldon.
16	" . . .	" . .	Heyford Iron Co., Limited	William Smith.
17	Glendon . .	Kettering . .	Glendon Iron Co. . .	George E. Checkland. J. P. Cramp.
18	Hunsbury Hill .	Northampton.	Hunsbury Hill Coal and Iron Co., Limited; F. Lenton, Secretary .	Thos. Pressland.
19	Irchester . .	Irchester . .	Butlin, Bevan, & Co. . .	Lewis W. Perrin.
20	Islip . . .	Thrapston . .	Islip Iron Co. . . .	..
21	Newbridge .	Twywell . .	Newbridge Iron Ore Co. .	Edward H. Clarke.
22	Raunds . . .	Thrapston .	The Raunds Iron and Limestone Quarries Co.	..
23	Ringstead . .	Ringstead . .	Butlin, Bevan, & Co. .	Lewis W. Perrin.
24	" . .	" . .	Newbridge Iron Ore Co. .	Edward H. Clarke.
25	Spratton . .	Brixworth . .	Attenborough & Co. . .	Richard Timms.
26	Stanton Gate .	Wellingborough.	Stanton Iron Works Co. .	John Hickman.
27	Thrapston . .	Thrapston .	Thrapstone Iron Ore Co., Limited	John Griffin. George C. Latimer.
28	Warren Hill . .	Kettering .	Kettering Iron and Coal Co., Limited . .	Herbert Sartoris. F. W. Preston.
29	Wellingborough.	Wellingborough.	Butlin, Bevan, & Co. .	Lewis W. Perrin.
30	" . .	" . .	Stanton Iron Works Co. .	John Hickman.
31	Woodford . .	Thrapston .	Arthur Arbuthnot . .	Samuel Pickett.
32	Wollaston . .	Wellingborough.	Butlin, Bevan, & Co. . .	Lewis W. Perrin.

Pig Iron Manufacture.—The first works established in Northamptonshire were those of Messrs. Butlin at Wellingborough projected by Mr. William Butlin of that firm, an engineer of some eminence, who carried out under his own supervision all the details of construction, and in the beginning of the year 1852 commenced the manufacture of pig iron, from the ironstone of the district, a sample of which it appears was deposited in the Northampton Museum. The Heyford Works succeeded, in the year 1857, under the auspices of Messrs. Pell & Co.; there were then two furnaces in operation at Wellingborough and one at Heyford, the make of pig iron amounting to 11,500 tons. In the

year 1866 the Glendon Iron Company blew in their first furnace at Finedon, increasing the number to three in the year 1869. In the year 1867 the Irthlingborough furnaces were put in blast and these possess some interesting features: the furnace casings, instead of being riveted as is usual, are put together by bolts, so that the fastenings are more secure and easier joined together and taken to pieces, effecting a saving in labour which more than compensates for the extra cost of the bolts. The boilers at these works are 30 feet in length and 6 feet in diameter. The blast engine for one furnace is worked with the average daily consumption of 28 cwts. of slack. The great economy gained by the boilers is attributed to the setting, which is a wheel shaft, the flues of which are increased in size as they approach the shaft, with a stack 3½ times the length of the boiler, the combustion is therefore complete without the loss of temperature in the shaft, which varies from 350° to 400° Fahr., and there is little or no smoke made.

The Stowe Iron Works near Weedon commenced operations about the year 1867; in the year 1871 the works at Islip, near Thrapston, of Mr. C. H. Plevins, were projected, followed by the works of the Northampton Coal, Iron, and Waggon Company, at Hunsbury Hill, in the year 1873, and the Towcester Works a year or two later. The Towcester Works are situated about 4 miles from Blisworth, consisting of two rotatory furnaces and the necessary plant for making iron and steel by the direct process, according to the patent of Dr. C. W. Siemens. By this system, even with the ordinary ores found in the locality, a crystalline iron of great purity as well as toughness is produced. The bars have been sold in Staffordshire and at Sheffield at a high price, being considered equal to Swedish bar as regards toughness and purity. The mode of working appears to be simple, as described by Dr. Siemens himself. A mixture of pulverulent ores combined with fluxing materials and reducing agents in suitable proportions, and of this from 4 to 5 tons are charged from a platform into the heated chamber to the depth of some 12 or 15 inches. Before charging the mixture some coke dust, or anthracite powder, is spread over the bottom and sides of the chamber for the protection of its silica lining. The heat of the furnace is thereupon raised to a full welding heat, care being taken that the flame is as little oxidising as possible. The result is a powerful superficial action upon the mixture, causing simultaneous reduction of the

ore and fusion of the earthy constituents. In the course of about two hours a thick skin of malleable iron is formed all over the surface of the mixture, which on being withdrawn by means of hooks, is consolidated and cleared of cinder under a hammer, and rolled out in the same heat into rough sheets or bars, to be cut up and finished in the refinery furnace or charcoal hearth; one skin being removed, the furnace is closed again, and in the course of one hour and a half another skin is formed, which, in its turn, is removed and shingled, and so on until, after 3 or 4 removals, the furnace charge is nearly exhausted. A fresh charge is then added, and the same operation repeated. The shingled metal so produced forms an excellent melting material for the open hearth or the Siemens-Martin process.

At Wellingborough it was at one time intended to roll the iron made there into bars, and for this purpose a large establishment was projected by Messrs. Hipkins & Sons, of West Bromwich, to be called the Wellingborough Bar Iron Company. Considerable progress was made with the erection of the works, plant and machinery were prepared, and puddling furnaces erected, but operations never actually commenced, and the buildings with their lofty chimney-stacks and flues still stand in close proximity to the Irthlingborough Iron Works of Messrs. Butlin and Co.

The iron works of the Cransley Ironstone Company, situated near Kettering, were projected about the year 1875, and in 1877 the works of the Kettering Iron and Coal Company at Warren Hill, situated about 2 miles from Kettering, were begun.

The works of the district have of late years considerably extended their plant; those of the Glendon Company, the most extensive in the county, have now 5 furnaces in operation, drawing the necessary ironstone from pits situated near the works; the plant of the company is at once extensive and complete, there being two powerful engines for the blast, one of them, made by the Lilleshall Company, being something like 150 horse-power, having 12 revolutions per minute. At the Glendon Works the gases from the furnaces are utilised for the stoves and boilers, and recently some new pits have been opened in close proximity to the works, affording an abundant supply of ironstone to the furnaces.

Near the Finedon Works an establishment has been recently erected, with the necessary appliances for the manufacture of glass bottles from the slag of the blast-furnaces; the works of

late have been standing, but a large number of bottles were made, thus demonstrating practically the process. Slag bottle manufacture would appear to be a profitable one, seeing that the necessary material can be had without cost, the iron-masters being but too glad to get the slag taken away from their works.

The works and companies, with the number of furnaces built and in blast in the year 1880, were as follows :—

Name of Works.	Owners.	Furnaces.	
		Built.	In Blast.
Cransley, Kettering	Cransley Iron Co., Limited	*2	2
Finedon, Wellingborough	Checkland and Fisher	*5	5
Irthlingborough "	Thomas Butlin and Co.	3	2
Heyford, Weedon	Heyford Iron Co., Limited	3	2
Hunsbury Hill, Northampton	Hunsbury Hill Coal and Iron Co., Limited	2	2
Islip, Thrapston	Islip Iron Co.	4	2
Stowe, Weedon	William M'Clure	2	0
Kettering	Kettering Iron and Coal Co., Limited	2	2
	Total	23	17

Resuming with the year 1858, the following table gives the make of pig iron, the number of furnaces built and in blast, and their average yield; the figures in the last column are subject to revision, inasmuch as in some years a few of the furnaces were but partially in blast :—

Year.	Furnaces.		Pig Iron Made.	Average Make of Furnace.
	Built.	In Blast.	Tons.	Tons.
1858	3	3	9,750	3,250
1859	4	3	12,800	4,266
1860	4	3	7,595	2,532
1861	4	3	7,730	2,576
1862	4	3	13,471	4,490
1863	5	3	14,590	4,863
1864	5	3	13,323	4,441
1865	5	4	14,700	3,675
1866	9	6	19,174	3,195
1867	9	5	25,184	5,035
1868	8	6	35,584	5,930
1869	8	7	41,500	5,928
1870	10	10	43,166	4,316
1871	12	9	60,512	6,723

* One building.

Since the year 1871 information is available, showing the quantity of coal and of ironstone used in the manufacture of pig iron; in Northamptonshire practically it is found that 60 cwts. of raw stone and a like amount of coal, previously coked, is employed in the production of each ton of pig iron; the coal includes all necessary for heating purposes, such as engine-fires, blowing-engines, &c.

In the year 1872 and since, the quantities of pig iron made and of coal and iron used were as follows, together with the furnaces built and in blast:—

Year.	Furnaces.		Pig Iron Made.	Coal Used.	Ironstone Used.
	Built.	In Blast.			
			Tons.	Tons.	Tons.
1872	12	9	59,424	183,523	...
1873	16	10	58,480	169,592	175,000
1874	18	14	53,760	152,138	159,280
1875	18	12	80,689	177,883	229,636
1876	20	11	84,916	212,093	241,958
1877	20	13	106,948	268,124	296,379
1878	20	15	138,370	345,681	391,687
1879	23	17	165,317	428,557	453,460
1880	23	17	178,714	470,165	528,501

The proportion existing in the above years between the iron made and material used, show the economy that has been secured; thus, in the year 1871, the coal and ore used, as already stated, was 60 cwts. of each to the ton of iron. In subsequent years less has been required, till in 1877 and 1878 the quantity did not exceed 50 cwts. of coal and from 56 to 57 cwts. of ironstone to each ton of pig iron. Gas-saving apparatus has hitherto been introduced into the metallurgical works of Northamptonshire to a very limited extent; if it had been adopted a still greater economy would have been attained. Glancing at the returns of production, it will be seen that within a period of 10 years the make of pig iron has increased upwards of threefold, and a saving has been effected of 10 cwts. of coal, equivalent to 18 per cent. on each ton of pig iron made.

The fuel chiefly employed in the furnaces of Northamptonshire is obtained from the South Yorkshire coal-field, that formerly used at the Wellingborough Works was Barnsley coal, an average sample of which, without being previously coked, contained of

sulphur 0·65 per cent.; of ash, 4·76 per cent, the ash consisting of shale, silicate of alumina, with a little protoxide of iron and traces of lime and magnesia.

Coke made from Barnsley coal and used at the Heyford Iron Works was found to contain 0·52 per cent. of sulphur, and 6·58 per cent. of ash.*

Considering the ironstone of Northamptonshire, and its reduction in the smelting works, various opinions have in recent years appeared relating to its character and the quality of the iron obtained therefrom; Mr. William Butlin of the Irthlingborough Iron Works near Wellingborough, who originally developed the ironstone deposits of the county and initiated the manufacture of pig iron thus defends the character of the industries in terms so cogent that they are reproduced here,† being worthy of consideration; he says:—

"These ores (brown hematite) are widely distributed through the county, are rich in iron, and vary considerably in their composition, but if smelted scientifically are capable of producing an excellent metal both for the foundry and the forge."

"It has been said of a certain district 'that the iron is made by brute force;' this is somewhat sarcastic, but it is to be feared the same remark might apply to this county.

"It is true good iron is made from these ores, but the larger proportion is very inferior, and it is the irregular quality produced which brings down the market price and brands it with a name it does not deserve—'common iron.'

"If good work is to be done, and the greatest advantage taken of what Nature has placed within our reach, it is highly important to have a good knowledge of the composition of the foreign matter in the ores, which, when melted together, constitute cinder, and the knowledge of the circumstances under which the most favourable results can be obtained. The fusibility of earthy compounds depends upon their chemical relations, and the greatest degree of fusibility that need be desired can be produced by means of clay, silex, and lime.

"We have argillaceous, silicious, and calcareous ores, and not unfrequently the various kinds are found in one and the same quarry. We have also an excellent limestone, admirably adapted

* For detailed Analyses of Coal of the Barnsley District, see Part I., p. 39.

† "Iron and Coal Trades Review," Dec. 3, 1880, p. 666.

for fluxing the ores, both as regards its physical structure and chemical composition."

Mr. W. Butlin subsequently refers to the suitability of the Northamptonshire pig iron for forge purposes, and its conversion into iron for hoops, sheets, and smaller sizes of bars, when the ores are judiciously selected and skilfully treated, and says:—"Iron is iron; it is not, however, pure metal with which we have to deal, but with the iron of commerce, containing many impurities more or less injurious, the quality depending pretty much on what is associated with it. The matrix, too, in the ore from which the iron is produced has also an important influence on the practical working of the metal in the puddling furnaces. Hence it is found advantageous to mix iron from different localities to improve the quality. The same rule applies to the puddling furnace as to the blast furnace. Iron made from argillaceous ores is mixed with those made from silicious and calcareous ores. Now Northamptonshire has an advantage in mineral deposits which few iron-making districts possess. As before stated, argillaceous, silicious, and calcareous ores are found in close proximity, and it requires only scientific selection and careful manipulation to make excellent forge-iron, having all the requisite fluxing elements and constituents in one pig without any other admixture for producing iron of the best quality and adapted for making hoops, sheets, and small sizes of bars, &c.

"Iron, however, when made from tender, friable ores, such as we have in this county, is not suited for manufacturing the larger sizes of iron; metal from more refractory ores is needed, that will stand the higher temperature required in heavy puddling." In conclusion, Mr. W. Butlin suggests the puddling of Northampton iron in the Casson-Darmoy patent gas furnace, which is admirably adapted for the conversion of iron from fusible compounds. "With mild treatment and the use of the furnace," he adds, "iron can and will be manufactured of a quality and at a price alike profitable to the smelter and iron-master."*

* "Iron and Coal Trades Review," Dec. 17, 1880, p. 717.

CHAPTER XIII.

LINCOLNSHIRE IRON INDUSTRIES.

Ironstone Deposits—Geology of North Lincolnshire—Scunthorpe, Frodingham—Analyses, Production, and Distribution of Ironstone—Mines in Operation in 1880—Pig Iron Manufacture—Production since 1864—Coal and Ore used in Pig Iron Manufacture.

Lincolnshire Ironstone Deposits.—A quarter of a century since the extensive deposits of iron ore, known as "hydrated oxide," and now extensively worked, were comparatively unknown. These deposits, now in process of rapid development, have given rise to the important, thriving, and increasing mining centres of Frodingham and Appleby, near Brigg.

Ironstone is also worked in other districts of Lincolnshire, as at Kirton-Lindsey, some eight miles north-east of Gainsborough, on the Manchester, Sheffield, and Lincolnshire Railway; at Caythorpe, some seven miles north of Grantham; at Claxby, between Market Rasen and Caistor, by the West Yorkshire Coal and Iron Company; and at Monk's Abbey and Greetwell, near the City of Lincoln, by the Mid-Lincolnshire Iron Company. Ironstone, it appears, was extensively worked in olden times in South Lincolnshire, but at present no workings are carried on in that division of the county.

The districts in the north-western area of the county, now extensively worked for ironstone, may be described as being within the area bounded on the north by the river Humber, on the west by the river Trent, and on the east by the river Ancholme. Within this area the geological formations dip in a direction from west to east, forming three principal escarpments, with long, sloping plains between them; the westernmost scarp is capped with Lower Lias, the middlemost with Lincolnshire limestone, and the easternmost is the chalk wold. These latter elevations are characteristic features of the country; the middle

escarpment, or limestone ridge, is also known as the "Cliff," and runs in a direction nearly due south from the river Humber to Lincoln, and even further southwards. The wold or easternmost escarpment tends south-east, towards Boston and the Wash, while the westernmost escarpment is the least continuous of the three.

The rocks of North Lincolnshire dip in a direction from west to east, and comprise liassic and oolitic strata, occurring in the following descending order, as given by the Rev. J. E. Cross, M.A., F.G.S., in his paper read before the Geological Society of London.*

Cornbrash and Great Oolite Clay.
Lincolnshire Limestone.
Upper Lias Clay.
Marlstone; "Rhynchonella bed."
Capricornus Clay.
"Pecten Bed" Ironstone.
Lower Lias; Scunthorpe Ironstone.
Bucklandi Beds.
Infra Lias (Rhœtic).
Kenper Marls.

The Keuper marls, the lowest of the above series of strata in the north-western area of Lincolnshire, occupies the bed of the river Trent. It appears that a few years since some sinkings were put down here for the piers of a railway bridge, and that they all went through this formation. Above the Keuper marls occur a series of clays, containing *Ammonites angulatus* and *Ammonites Johnstoni;* both these ammonites appear in the lowest beds, but the first-named has a higher range in the series of clays through a zone of, say, 150 feet or more. Upon these angulatus beds repose a series of limestones and clays, distinguished by the presence of *Ammonites Bucklandi.* In these and the angulatus beds, occur the vast deposits of ironstone which are worked at Scunthorpe. The bed containing this deposit attains in some places a thickness of 27 feet, and is found cropping out at the surface, and it extends over a large area. The ironstone is wrought in open workings, as in Northamptonshire, and, having a slight "over burden" easily removed, is worked inexpensively.

This important ironstone deposit, covering the whole wide

* "Journal of the Geological Society," vol. xxxi., 1875.

plain of the village of Scunthorpe, is described as commencing below with a hard limestone band, and, in somewhat similar bands above, most of the fossils lie. These are intercalated with softer bands of a darker brown colour and rubbly texture, intermingled with a brown earthy deposit. The Lincolnshire ironstone, it may be observed, differs widely from the Cleveland ironstone, and is in fact on a much lower geological horizon. As already stated, the Scunthorpe ironstone occurs in the lower part of the Lower Lias, an occurrence which is believed by Mr. Cross to be almost unique in this country.

The Lower Lias clay previously referred to, in which occurs the massive seam of ironstone, has in North Lincolnshire a thickness of 90 feet; no openings, however, of any importance have hitherto been made in depth.

Superimposed on the Lower Lias series is the Middle Lias, in which there is a seam of ironstone 4 feet in thickness, in which *pectens* occur in profusion, and hence it has been designated the "Pecten Ironstone." The junction between the Lower and Middle Lias is represented by a thickness of some 66 feet, consisting of blue clay, containing throughout in the centre of cement nodules a characteristic species, the *Ammonites maculatus* (Capricornus of Schlotheim). At Santon, in a railway cutting, a good section of this clay is exposed, capped by a thin bed not exceeding 18 inches in thickness, containing a confused mass of broken belemnites and other shells, together with many coprolites and much pyrites, the whole of a bright green colour.

The seam of ironstone occurring in the marlstone or Middle Lias is sometimes called the "Rhynchonella bed," from the circumstance that fossils of that genus occur therein in great profusion; the lias bed is described as consisting of a hard, light-grey limestone, weathering to brown, and seems to contain *Ammonites spinatus* towards the lower part, and *A. communis* and *serpentinus* in the upper. Above the Rhynchonella bed occurs the Upper Lias, hitherto but little explored; it has an average thickness of 60 feet, and consists chiefly of a blue shale, but showing no trace throughout the north-western district of the overlying Upper Lias sands.

Extending away to the east, and above the Upper Lias upon which it rests, appears the middle escarpment previously referred

to, occupied by the Inferior Oolite, which in this district is often termed the Lincolnshire limestone. It has an average thickness of 36 feet, including its partings of clay. Next above occurs the Great Oolite, consisting of limestones and clays, the latter in parts of a bright green colour, some 40 feet in thickness, and the representative no doubt of some subdivision of the oolite series. But one other formation, the "Cornbrash," remains to be referred to. The Cornbrash occupies the surface away to the east till the alluvial deposits of the river Ancholine are reached. The foregoing will show generally the occurrence and succession of the strata of the liassic and oolitic formations in North Lincolnshire, and the position of the ironstone deposits, for a more detailed account of which reference should be made to the Rev. J. A. Cross's paper in the "Journal of the Geological Society of London." *

Frodingham, the centre of the iron-mining district of North Lincolnshire, is situated on the Manchester, Sheffield, and Lincolnshire Railway, which connects it with the ports of Hull and Grimsby. Although ironstone is obtained elsewhere in the county, it is here that the manufacture of pig iron is carried on. About twenty-three years since attention was directed to the deposits by the Messrs. W. H. and G. Dawes, of the Milton and Elsecar Ironworks, Barnsley, in the West Riding of Yorkshire. This firm constructed a railway, from the river Trent to the outcrop of the bed, to facilitate the shipment of ironstone to their works. The ironstone seam is covered by a deposit of drift of varying thickness, being shifted about by high winds, so that the land, from an agricultural point of view, is of little value. Before the discovery and development of the ironstone deposits the district was little more than barren moorland, the village itself at that time being but a hamlet; of late years it has become a town of some importance, and is still steadily extending, while the value of the land has greatly increased. Mr. George Dove, junr., who some years since carefully examined the district, says that "the bed, which is almost entirely free from faults, inclines gently to the east, but where it is now being worked at, and within one and a-half miles of the outcrop, the amount of 'bareing' required is very small, in no place exceeding 3 feet. The labour

* Vol. xxxi., 1875, p. 115.

employed in raising the stone is of the commonest and most unskilled description, blasting only being required in getting the stronger portions of the bed; the whole operation is simply one of quarrying." Mr. Dove further adds that the deposit is not of very regular formation; it consists of bands of stone, some consolidated, others unconsolidated, of various appearances, mechanical conditions, and compositions, which are again broken up by bands of ferruginous limestone of varying thicknesses.

Before proceeding to consider the production of ironstone in this locality, the other districts of Lincolnshire, in which local deposits of ironstone occur, may be briefly referred to, not only of those deposits occurring in strata already referred to, but also in other geological formations of more recent age.

In South Lincolnshire the marlstone rock (Middle Lias) was formerly worked, as also was the ironstone of the Northampton sand; the latter is of the age of the Inferior Oolite. A band of good ironstone, occurring at the base of the "Upper Estuarine Series," was also wrought in ancient times. Some years back ironstone was worked at Overton, near Peterborough, in Northamptonshire, in the "Great Oolite Clay," which is the equivalent of the Forest Marble of the South of England; the workings have, however, been long since abandoned, on account of the great thickness of bareing necessary to be removed before the stone was reached.

A brown iron ore of oolitic structure, forming a bed 6½ feet thick, occurs in the Tealby Series or Middle Neocomian, occurring at Tealby, some four miles north-east of Market Rasen, and is much valued for admixture with the argillaceous ores of Yorkshire and the calcareous ores of Lincolnshire. Ironstone is also wrought at Caythorpe, near Grantham, South Lincolnshire (a hydrated oxide); in the year 1880 the quantity raised amounted to 73,680 tons, put in trucks at the workings at an average price of 3*s*. per ton. This ore is said to contain 31 per cent. of metallic iron, from 18 to 20 per cent. of lime, and from 1·25 to 1·50 per cent. of manganese; is in good demand, and meets with a ready sale.

To those interested in the subject of the occurrence of the ironstone deposits in the liassic and oolitic rocks, the recent work of Professor Judd, F.G.S.,* will possess especial interest. In this

* "Geology of Rutland," Professor J. W. Judd, 1875.

important contribution to geological science the author fully discusses the classification and correlation of the Jurassic rocks of the Midland district or counties of England, including Rutland and parts of Lincoln, Leicester, Northampton, Huntingdon, and Cambridge.

Analyses of the Ironstone.—The stone raised in the Frodingham district, like that in other localities in Lincolnshire, has been fully investigated and its constituents determined by Mr. George Dove, junr., of the Redbourn Hill Iron Works, from whose interesting paper on the "Frodingham Iron-fields" * the following are selected. In the various mines worked on Mr. R. Winn's estate the yield of metallic iron varies according to portions of the seam used; the working face of the quarry, from which the samples were taken, has a thickness of 16 feet, increasing to 18 feet and even more. The seam is divided by Mr. Dove into 11 distinct bands; the iron exists in the form of peroxide; the seam has a maximum thickness of 27 feet, the bands of which it is composed vary in thickness from 9 inches to 3 feet 6 inches, many of them, however, containing stone of very inferior quality, a sort of ferruginous limestone, which it is always desirable to reject. The top band of the seam is described as mechanically very small and friable, resembling in appearance brown, ferruginous sandstone, highly oxidised and tolerably dry, the other bands containing a large amount of moisture :—

RESULTS TABULATED.

Constituents.	Top Band.	Second Band.	Fourth Band.	Sixth Band.	Eighth Band.
Peroxide of iron	61·79	48·71	47·14	47·36	41·14
Protoxide of manganese	2·70	3·05	1·72	2·09	0·79
Silica	10·77	12·85	11·95	13·00	24·40
Alumina	6·38	3·85	4·08	4·85	6·62
Lime	1·79	9·58	11·45	10·60	8·18
Magnesia	1·10	2·51	2·97	3·02	2·10
Sulphur	0·08	0·06	0·10	0·07	0·04
Phosphoric acid	1·46	1·12	0·87	0·82	1·12
Combined water	14·43	12·47	12·40	11·90	10·70
Carbonic acid	traces	6·15	6·87	6·74	5·28
Total	100·50	100·35	99·55	100·45	100·37
Metallic iron, dried stone	43·25	34·10	33·00	33·15	28·80
,, wet stone	38·94	30·47	29·44	27·08	25·04
Moisture	9·97	10·65	10·79	18·32	13·04

* "Journal of the Iron and Steel Institute," 1876.

Some parts of the great seam are highly manganiferous; these bands do not appear in the face of the workings from which the above samples were taken for analysis, but appear in another part of the quarry; these also have been examined by Mr. Dove; the one sample, consisting of scales of peroxide of manganese, taken of the manganiferous ironstone band, occurring about 13 feet from the top of the bed; the second sample, from that part of the band, appearing about 7 feet from the top of the bed; and the third, an average sample of the band itself. The annexed show the results:—

Constituents.	1.	2.	3.
Peroxide of iron	23·71	38·07	39·36
Peroxide of manganese	32·82	11·40	3·80
Silica	14·00	18·80	24·67
Alumina	3·09	5·01	5·41
Lime	9·46	6·38	6·83
Magnesia	...	2·82	2·27
Sulphur	0·02	0·04	0·06
Phosphoric acid	*...	0·52	0·56
Combined water	*...	14·37	13·27
Carbonic acid	*...	3·02	3·90
Total	...	100·43	100·13
Iron in dried stone	16·60	26·65	27·55
Moisture	10·04	21·32	16·41

From an examination of these analyses the variable composition of the bed will be understood. Mr. Dove further adds that the greatest care is necessary in the selection of the stone before it is charged into the furnace; and further, that unless this selection be properly understood and attended to, serious disorganization of the working of the furnace must inevitably result.

The seam in the neighbourhood of Brigg, a few miles to the south-east of Frodingham, has been reported upon by Mr. Charles Tookey, of the Royal School of Mines, giving the following results; for comparison is appended side by side analysis of the Northamptonshire ore, from the neighbourhood of Wellingborough:—

* Not estimated.

Constituents.	Lincolnshire, Brigg.	Northamptonshire, Wellingboro'.
Sesquioxide of iron	58·10	50·31
Protoxide of iron . . .	...	trace
Peroxide of iron . . .	...	...
Protoxide of manganese . .	0·88	0·51
Alumina	3·00	7·25
Lime	4·15	11·76
Magnesia	0·96	0·62
Carbonic acid	1·08	7·98
Phosphoric acid . . .	1·40	1·28
Silica	...	0·22
Bisulphide of iron . . .	...	0·17
Water hygroscopic and combined	16·46	11·00
Ignited insoluble residue . .	13·75	9·33
Total . . .	99·78	100·43
Metallic iron	40·67	35·37

The above residue of the Brigg ironstone is made up of 11·70 per cent. of silica, of which 7·45 per cent. was in combination, and 4·25 per cent. existed as sand, the remaining 1·95 per cent. consisting of alumina and lime.

The ironstone raised at Monk's Abbey, and at Greetwell, near the city of Lincoln, worked by the Mid-Lincolnshire Iron Company, is in great request by the ironmasters of the Frodingham district, who use the stone in admixture with the Frodingham ore, in proportions varying from one-eighth to one-quarter, and with the most satisfactory results, both as regards the regularity of the working of the furnace and low consumption of fuel which are obtained. Since its introduction the difficulties formerly existing in the excess of lime in the native ore has been much lessened. The following is an analysis of the ore:—

MID-LINCOLN STONE.

Peroxide of iron	60·91
Manganese	traces
Alumina	5·47
Lime	1·60
Magnesia	0·06
Phosphoric acid	1·02
Sulphur	0·03
Insoluble matter	15·80
Carbonic acid and water	15·35
Total	100·24

The equivalent of metallic iron contained in this stone is 42·64 per cent., the insoluble matter consisting of 13·24 per cent. of silica and 2·56 per cent. of alumina. A clay obtained at Santon has sometimes been used in admixture with the ores of the northern districts of Lincolnshire, but, commercially, it does not appear to have succeeded so well as with a certain proportion of the stone obtained near the city of Lincoln.

Comparing the constituents of the Frodingham stone with that of Cleveland the results show favourably in an analysis of the latter, published in the "Iron Ores of Great Britain," Part I. Phosphoric acid gives 1·86 per cent., and protoxide of iron 39·92 per cent. Some of the better varieties of Lincolnshire stone, examined by Mr. John Pattinson, of Newcastle-upon-Tyne, give the following results:—

Constituents.	No. 1.	No. 2.	No. 3.
Peroxide of iron	67·00	72·14	57·86
Protoxide of iron	nil	nil	nil
Protoxide of manganese	0·31	0·62	0·24
Alumina	4·20	3·47	7·10
Lime	1·82	1·73	2·92
Magnesia	0·36	0·34	0·69
Carbonic acid	1·27	0·23	1·67
Silica	9·87	8·00	14·17
Sulphur	0·02	0·03	trace
Phosphoric acid	0·70	0·57	0·80
Combined water	12·10	11·24	10·24
Moisture	2·17	1·59	4·29
	99·82	99·96	99·98
Metallic iron	46·90	50·50	40·05

Mr. J. Roseby, who has long been identified with the development of the ironstone of the district, expresses his opinion favourably, stating that a very fine quality of iron, suitable for almost any purpose to which that metal is applied, could be easily produced; all that would be required being care in the selection of the stone.

Production and Distribution of Ironstone.—The development of the North Lincolnshire ironstone deposits commenced about the year 1858 in the neighbourhood of Scunthorpe, the property of Mr. Rowland Winn, M.P., whose name, with the names of the Messrs. Dawes previously referred to, are so intimately associated with the early history and subsequent

progress of this the most recently discovered ironstone-field in the kingdom. The stone raised at Frodingham and sent out of the county in the year 1859 was smelted at the Milton and Elsecar Works in Yorkshire, in admixture with the clay iron ores of the coal measures of that district, and were found to work well in the furnaces, producing iron of good quality.

The output in the year 1859 did not exceed 2,000 tons, increasing in the following year to 16,192 tons, and in the year 1861 to 32,709 tons. In succeeding years the returns of production appear as follows:—

Year.	Ironstone.	Year.	Ironstone.
Nos.	Tons.	Nos.	Tons.
1861	32,709	1871	217,767
1862	50,323	1872	256,149
1863	69,618	1873	350,281
1864	74,619	1874	463,239
1865	124,958	1875	573,336
1866	175,720	1876	573,374
1867	192,213	1877	508,749
1868	200,699	1878	683,685
1869	220,524	1879	695,326
1870	216,829	1880	1,154,584

The great bulk of production is obtained from the Frodingham district, which includes the stone dug in the Scunthorpe area, where it was first raised. Other deposits discovered at Claxby, and first opened out by Mr. W. Firth, of Leeds, are now largely worked and sent into Yorkshire for the Ardsley Main Works, which belong to the West Yorkshire Iron and Coal Co. The details of production, with the value of the ore, appear below for the year 1880:—

District or Mine.	Quantities.		Value.		
	Tons.	Cwts.	£	s.	d.
Caythorpe	73,680	14	11,002	1	9
Claxby, Caistor	27,500	0	4,125	0	0
Crosby, Frodingham	89,130	7	13,369	11	0
Greetwell, Lincoln	77,638	0	15,527	12	0
Gunbrose, Parkgate Iron Co.	145,899	0	21,884	17	0
Glebe	47,165	0	7,074	15	0
Frodingham Iron Co.	145,642	0	21,846	6	0
Trent Iron Co.	148,138	0	22,220	14	0
North Lincolnshire Iron Co. Appleby Iron Co. Redburn Hill	357,353	0	53,602	19	0
Normanby, Crosby	42,438	0	6,365	14	0
Total	1,154,584	1	177,019	9	9

The ironstone worked in the neighbourhood of the City of Lincoln contains silica in considerable quantity, and on this account is valuable in admixture with the Frodingham stone, which is calcareous. The annexed figures for a few years show the quantity raised of the siliceous ores from Lincoln, conveyed to, and used in, the ironworks of North Lincolnshire since the year 1874:—

Year.	Tons.	Year.	Tons.
1874	40,888	1878	92,264
1875	80,890	1879	76,908
1876	96,443	1880	77,638*
1877	97,977		

Distribution of the Ironstone.—The districts of North Lincolnshire, in which the iron mines are mainly situated, are traversed by the Manchester, Sheffield, and Lincolnshire Railway, affording facilities for the transport of the ironstone to the north, while a branch of the same system, the Trent and Ancholme Line, puts the district in communication with Barnsley, South Yorkshire, the West Riding of Yorkshire, Derbyshire, and Nottinghamshire; the distance from Barnsley not exceeding 35 miles.

In the year 1864 the above-named railway carried out of the county 25,363 tons, increased to 28,469 tons in the year 1865. In later years the following quantities were received by the Manchester, Sheffield, and Lincolnshire Railway Company, and distributed in districts remote from Lincolnshire:—

Year.	Frodingham.	Holton-le-Moor.	Lincoln.	Total.
	Tons.	Tons.	Tons.	Tons.
1867	86,587	...	...	86,587
1872	138,279	61,097	...	199,376
1873	205,677	78,489	...	284,176
1874	141,289	42,731	40,888	224,908
1875	217,630	45,328	80,890	343,848
1876	164,101	47,037	96,443	307,581
1877	172,265	23,195	97,977	293,437
1878	188,209	18,015	92,264	298,488
1879	150,298	2,565	76,908	229,771
1880	262,359	21,937	73,948	358,244

The value of the ironstone at the pits, put into trucks, varies,

* Of the value of £15,627, or 4*s*. per ton.

according to quality, from 2*s*. 9*d*. to 3*s*. and 3*s*. 3*d*. per ton, the ironstone also bearing a moderate charge for transport. In recent years it has been used in works near Middlesborough, and at Wingerworth and other iron works in Derbyshire, and even in Lancashire.

The annexed list shows the localities of the mines, their proprietors and managers, in the year 1880:—

No.	Name of Mine.	Situation.	Name of Proprietor or Company.	Name of Manager or Agent.
1	Appleby	Brigg	Cliff & Sons	F. Walsham
2	Claxby	Market Rasen	W. Yorkshire Iron and Coal Co.	Dr. England
3	Caythorpe	Grantham	M. C. Cohen	M. C. Cohen
4	Normanby	Frodingham	William Cook & Co., Limited	C. F. Roseby
5	Frodingham	Brigg	Charles Winn	John Roseby
6	"	"	Cliff & Sons	F. Walsham
7	Gunbrose	"	Park Gate Iron Co., Limited	George Reed
8	Greetwell	Lincoln	Mid Lincolnshire Iron Co.; W. J. Roseby, Man. Partner	R. Ramsden
9	Monks Abbey	"	" "	"
10	Trent	Scunthorpe	Mrs. W. H. Dawes	J. H. Dawes
11	Glebe	Frodingham	Staveley Coal and Iron Co. Lim.	Charles Markham, Man. Director.

Pig Iron Manufacture.—This industry in North Lincolnshire is of comparatively recent date. About the year 1862 the Messrs. Dawes, of the Milton and Elsecar Iron Works, near Barnsley, laid down and erected the Trent Iron Works. The same firm had previously been engaged in the development of the ironstone deposits of the district, which were conveyed to the works near Barnsley, above named, and smelted in admixture with the argillaceous ores of the coal measures, producing a quality of iron suitable for mill, forge, and foundry purposes. The Trent Works commenced operations in 1863. In the year 1866 the Frodingham Iron Company, situated at Scunthorpe, were started by Messrs. Cliff and Hurst, and in the year 1867 this firm had two furnaces in blast. The North Lincolnshire Iron Company followed about the same date with one furnace, blowing in a second furnace in the year 1871. The next metallurgical works projected were those of the Lincolnshire Iron Smelting Company and the Redbourn Hill Iron and Coal Company, the former about the year 1872, and the latter more recently, in the year 1874, the last works established being those of the Appleby Iron Company, who commenced operations about the year 1877.

The Lincolnshire furnaces vary considerably in size and

capacity; those of the Trent Company, erected in 1862 and 1863, are 40 feet high and 14 feet in diameter at the boshes; others erected by the same firm in the year 1875 are 60 feet high and 18 feet in the boshes. Those of the Frodingham Company vary from 63 to 65 feet in height, having a diameter at the boshes of 18 feet. The furnaces of the North Lincolnshire Iron Company, erected in 1865 and 1867, are 70 feet and 52 feet in height, and 20 feet in the boshes; the furnaces erected by the same company in the year 1875 being 60 feet in height and 20 feet 9 inches in the boshes.

The most capacious furnaces in the district are those of the Redbourn Hill Iron and Coal Company, 75 feet in height and 20 feet diameter in the boshes. The furnaces of the Lincolnshire Smelting Company are 70 feet in height and 20 feet diameter in the boshes, while those of the Appleby Iron Company are 62 feet in height and 18 feet diameter in the boshes.

The Redbourn Hill furnaces, the largest in the district, possess some interesting features, designed by Mr. Dobbs, of Middlesborough, and constructed so as to deal with the excess of moisture contained in the ironstone. The arrangements are thus described: "The gas may be taken off either at the top or at a point 22 feet lower down, and the arrangement is to take off at the lower point sufficient gas to supply the stoves and boilers, and then to allow the surplus gas to pass through the material above the point, and to escape, with the moisture driven off, through an escape-pipe fixed on the upper gas box." The plan appears to work well; the lower flue, however, requires attention, as it is quickly choked with dust, and renders frequent cleaning necessary. In the open-topped furnaces of the district the gas is taken off at distances varying from 8 to 15 feet from the top, and with sufficient draft of chimney enough can be obtained to do away entirely with the use of coal at either stoves or boilers. The stoves employed throughout the district are of the ordinary Cleveland type, and the temperature obtained varies from 800° to 1000° Fahr.

The first ton of pig iron was cast, in the year 1864, at the Trent Works; in the same year the united production of Lincolnshire and Northamptonshire amounted to 22,823 tons, increased in the following year to 25,728 tons. In subsequent years the furnaces built and in blast, and the make of pig iron,

in Lincolnshire, was as follows till the year 1871, to which is appended the average yield per furnace :—

Year.	Furnaces.		Pig Iron Made.	Average per Furnace.
	Built.	In Blast.		
	Nos.	Nos.	Tons.	Tons.
1864	5	3	9,600	3,200
1865	5	3	11,028	3,676
1866	6	3	13,765	4,588
1867	6	5	25,579	5,116
1868	6	5	33,999	6,780
1869	6	5	33,768	6,752
1870	6	4	31,690	7,922
1871	7	4	30,122	7,530

Coal and Iron Ore used in Manufacture.—The fuel employed is Durham coke, and coke obtained from the South Yorkshire coal-field, analyses of which will be found in each of those coal-producing districts.

In the following table appears the number of furnaces built and in blast, the make of pig iron, and the quantities of coal and ore used in its manufacture, in each year since 1871 :—

Year.	Furnaces.		Pig Iron.	Coal Used.	Ore Used.
	Built.	In Blast.			
	Nos.	Nos.	Tons.	Tons.	Tons.
1871	7	4	30,122	84,000	106,000
1872	9	7	36,989	105,658	130,000
1873	13	9	52,076	142,236	188,050
1874	15	8	67,260	167,188	253,596
1875	21	14	111,683	303,000	393,000
1876	21	16	125,198	297,676	454,836
1877	21	10	116,857	265,232	428,459
1878	21	11	125,043	270,050	453,053
1879	21	14	131,678	261,395	465,818
1880	21	15	207,704	481,807	790,819

The above figures show a varying average; in the year 1871 there were 56 cwts. of coal, and in 1872, 57 cwts. to each ton of pig iron made, while in 1878 the quantity did not exceed 43 cwts., a saving in seven years of 13 cwts. of coal in each ton of iron made. This economy is mainly due to the more extensive use of Durham coke, and the utilization of the waste gases. The

foregoing figures are actual returns, and include all coal used in all processes carried out in the works. In the close-topped furnaces of the district it has been determined, all conditions being favourable, the furnace in good working order, that the consumption of Durham coke does not exceed 24 cwts., and even less. This would be equivalent to from 34 to 35 cwts. of coal in the furnace, the remainder being otherwise employed in the works. Again, in the open-topped furnace, using the same class of coke, from 27 to 28 cwts. are employed, equivalent to 40 cwts., taking in each case the yield at 70 per cent., while in the same type of furnace using the South Yorkshire coke the consumption is found to be from 30 to 32 cwts., equal to from 49 to 51 cwts. of coal, the latter yielding of coke 62 per cent.

The ironstone, which is chiefly employed in the raw state, requires from 70 to 71 cwts., owing to the lime it contains; when calcined in clump and exposed to the weather it decrepitates, and it has been suggested that this result might be got over if the stone was charged hot from the calcining kiln to the furnace. The amount of moisture contained in the raw stone varies with the season, amounting in the winter months to 30 per cent., greatly increasing the consumption of fuel. As already stated, the Lincoln stone is used in admixture with the Frodingham stone; the Santon clay (worked at Santon, some four or five miles from Brigg), also referred to, is occasionally used as a fluxing material. Its composition is as follows, containing 4·75 per cent. of iron :—

SANTON CLAY.

Silica	50·10
Alumina	22·72
Peroxide of iron	6·78
Lime	4·28
Magnesia	1·56
Water and organic matter	14·33
Total	99·77

CHAPTER XIV.

NORTH WALES IRON INDUSTRIES.

Iron Ore Deposits of Denbighshire and Flintshire—Analyses and Production of Iron Ore—Population employed in Iron Mining—Succession of Strata in Denbighshire—Pig Iron Manufacture—Early History—Production—Works in Operation in 1880—Malleable Iron Works—Coal and Iron Ore used in Pig Iron Manufacture.

Iron Ore Deposits.—Some ten years since a discovery was made of a rich argillaceous iron ore, consisting of 6 or 7 bands of a dark ironstone on the out-crop of the Ruabon coal-field at Trefechan, and some 90 or 100 yards below the Llwynenion or Half-yard coal of that district. This ironstone does not appear to have been wrought to any extent, though it has been known to yield iron of very good quality. On an adjoining property near Trefechan, it is stated that these ores were successfully reduced by a former proprietor who, between the years 1811 and 1824, produced some 30,000 tons of pig iron from ores raised there, some specimens of the iron referred to showing a curiously close-grained structure.

In Flintshire, at the Cwm Mountain, near Prestatyn, a deposit of red hematite occurs, about 1½ miles south-east of the far-famed Talargoch lead mine. The ore here occurs almost entirely as a breccia of angular fragments, cemented by crystalline carbonate of lime. It fills very irregular lodes in the carboniferous limestone, and extends also in an irregular form between the limestone and underlying Silurian rocks to a short distance from the lodes.

In the neighbouring hill, Moel Hirradug, several small deposits have been worked, some, it is supposed, at a very early date. The ore occurs in "pockets," produced by the sudden widening out of small joints in the carboniferous limestone. These deposits have

been worked since the year 1870, and appear to contain both nickel and cobalt: an average assay giving cobalt 2·05 per cent., nickel 0·75 per cent, with oxide of iron. Other deposits have been worked at Caerwys, and at Gled-lôm, near Ysceifiog, and in all these cases the iron ore is found in the lowest beds of the limestone.

A number of similar pockets are being worked in the small patch of limestone near Bodfari. They are here connected with a system of strong joints, having a west-north-west direction.

Analyses of the Ironstone.—The argillaceous ores of Denbighshire contain from 30 to 36 per cent. of metallic iron. The ironstone raised at Trefechan gives 36·31 per cent. of metallic iron, and on calcination 51·54 of metallic iron. A complete analysis of this ironstone, by Mr. John Collins of Bolton, exhibits the following constituents:—

RESULTS TABULATED.

Metallic iron	36·31
Manganese	1·31
Magnesia	3·39
Lime	3·03
Alumina	0·79
Water	0·96
Carbonic acid	33·06
Phosphoric acid	1·09
Sulphuric acid	trace
Ignited insoluble matter	20·06
Total	100·00

It is said of this ironstone that it is unusually free from impurities and comes comparatively clean from the mine, requiring but little preparation for the calcining heap.

Production of Ironstone.—The great bulk of the ironstone smelted in the furnaces of North Wales is obtained from the ironstone measures of the Denbighshire coal-field in the neighbourhood of Ruabon. The quantity raised in the year 1855 amounted to 65,820 tons; hematite ores raised in the same year in the neighbourhood of Rhyl and Cwm Mountain in Flintshire amounting to 1,320 tons. In the years 1856 and 1857 the total quantities of all kinds of iron ore and stone were respectively 65,914 tons and 70,374 tons, the details of production being as follows in each of those years:—

Collieries and Mines.	1856. Quantities.	1857. Quantities.
	Tons.	Tons.
Afon Eitha	367	367
Brymbo	29,558	30,715
Bryn Mally	1,648	1,500
Broughton	82	90
Coed Poeth	1,890	1,800
Cwm Mountain (Hematite)	...	1,650
Dolydd	200	350
Ffrwd	6,000	6,000
Llwynenion	1,200	1,150
Nannerch	...	1,080
Plasissa	6,397	7,142
Quinta	50	...
Trafynant	1,500	1,430
Vron	37	100
Ruabon	16,985	17,000
Total	65,914	70,374

Smaller quantities obtained from other collieries in 1856 make the total 70,000 tons; and 20,000 tons, in 1857, brings the total yield for that year up to 90,374 tons. The production of iron ore of all kinds in North Wales since 1858 has been as follows :—

Year.	Denbighshire.	Flintshire.	Carnarvonshire.	Sundry Mines.	Total North Wales.
	Tons.	Tons.	Tons.	Tons.	Tons.
1858	48,935	3,590	1,650	35,000	88,575
1859	38,822	3,500	1,750	39,000	87,073
1860	85,000*	...	97	...	85,097
1861	82,500	4,000	...	...	86,500
1862	51,700	2,456	...	...	54,156
1863	27,550	732	...	...	28,282
1864	23,750	5,377	...	...	29,127
1865	97,500	750	...	...	98,250
1866	55,690	992	...	...	56,682
1867	43,582	500	...	...	44,082
1868	35,813	500	...	...	36,313
1869	33,431	62	...	...	33,493
1870	59,140	100	...	...	59,240
1871	51,887	...	...	...	57,887
1872	23,045	4,730	...	...	27,775
1873	25,000	3,860	...	9,426	38,286
1874	41,157	1,070	...	...	42,227
1875	39,907	2,277	...	...	42,184
1876	40,952	...	...	...	40,952
1877	41,711	498	...	...	42,209
1878	43,082	378	...	...	43,460
1879	38,936	392	...	...	39,328
1880	41,413	1,603	...	...	43,016

* Including produce of Flintshire.

The great bulk of ironstone raised in North Wales is of the variety known as argillaceous carbonate. The average value of the ore in the year 1870 was about 7*s.* per ton, increased to 14*s.* per ton in 1872, receding in 1875 to 10*s.* per ton, since which date it has remained with but little variation.

Population employed in Iron Mining in Flintshire.—In the mines raising hematite in two or three localities in Flintshire, the following were the numbers employed in each year since 1873, and although the numbers are small and the produce of iron ore unimportant, it cannot but be interesting to note up all information bearing on the subject:—*

Year.	PERSONS EMPLOYED.		Total.	Iron Ore Raised.	Average per Man.
	Under Ground.	Above Ground.			
	Nos.	Nos.	Nos.	Tons.	Tons.
1873	46	15	61	4,730	77
1874	36	9	45	4,716	104
1875	19	4	23	1,069	46
1876	2	...	2	26	13
1877	2	12	14	498	35
1878	9	4	13	378	29
1879	4	9	13	232	18
1880	9	...	9	950	105

The Denbighshire iron furnaces are chiefly supplied by the ironstone measures of the coal-field. In the year 1851 when, as already stated, the late Mr. Samuel H. Blackwell exhibited in the Great Exhibition a most interesting series of iron ores, illustrating the iron making resources of the United Kingdom, the ironstone measures of Denbighshire were thus referred to, showing the following succession of strata in section:—

STRATA.	THICKNESS. Ft.	In.
Three-yard Coal	9	0
Brassey Coal	2	3
Upper-yard Ironstone; four irregular courses averaging about	0	7
Upper-yard Coal	2	6
Red Coal Ironstone Balls.		
Red Coal	1	6
Stone Coal Ironstone; four courses.		
Stone Coal.	2	9
Half-yard Coal	1	6

* H.M. Inspectors of Mines Reports.

STRATA (*continued*).	THICKNESS. Ft.	In.
Two-yard Coal Ironstone.		
Lower-yard Ironstone.		
Lower-yard Coal	3	0
Wall and Bench Ironstone; six courses, equal to 12½ in., lying in about 7 ft. of ground.		
Wall and Bench Coals	3	0
Llwynenion Ironstones; fifteen courses, averaging 30 in., all worked with the coal in three lifts; will yield from 8,000 to 9,000 tons per acre.		
Llwynenion Coal	1	6

Production of Pig Iron.—As far back as the year 1740, the reduction of the ores of iron appears to have been carried on in North Wales in Denbighshire. The returns of production for that year show the existence of two blast furnaces, yielding 550 tons of pig iron, the total make of the 59 furnaces in operation in England and Wales at that time being 17,350 tons, giving an average yield per furnace of 294 tons. Advancing to the year 1788, when the aggregate production of pig iron in England and Wales amounted to 61,300 tons, of which 13,100 tons were charcoal iron, and 48,200 tons coke pig iron, the former the yield of 24 and the latter of 53 furnaces, North Wales at this period does not appear to have had any share in the manufacture. Later, in the year 1796, Denbighshire appears to have had five furnaces in operation, yielding 6,230 tons of pig iron. The details of production were the result of an inquiry instituted by the House of Commons, at the time that Mr. Pitt proposed to levy a tax on coal, to be paid, without exception, at the pit's mouth, a measure subsequently abandoned. The works in operation in 1796, with the make of each, is recorded as follows:—

WORKS.	TONS.
Brymbo	884
Brymbo Gate	728
Pentroba	1,560
Penyvron	1,498
Ruabon	1,560
Total	6,230

The total production of pig iron in Great Britain in 1796, according to the returns of the Excise authorities, is set down at 167,311 tons. Subsequent inquiries showed the quantities actually made not to have exceeded 125,080 tons; even this is a considerable advance on the production of 1788. In the beginning of the present century (1806), the two principal ironworks

in Denbighshire were those of Ruabon of Messrs. Rowland & Co., and those of Brymbo of Mr. S. Wilkinson; the Ruabon furnace producing 1,463 tons of pig iron, and the Brymbo, 462 tons, the last named works being in operation but a part of the year. The total make of pig iron in Great Britain in 1806 being 243,851 tons, the yield of 161 furnaces.*

Not again until the years 1823 and 1830 are returns available. In the last named year Mr. F. Finch, in his inquiry carried out for the Government, ascertained that the make of 7 furnaces in North Wales in 1823 was 13,100 tons of pig iron, increased in 1830 to 12 furnaces and 25,000 tons, showing an increase of 12,000 tons in 7 years. Mr. H. Scrivener * gives the following as the number of furnaces and make of pig iron in the years named:—

Year.	Furnaces.	Pig Iron Made.
	Nos.	Tons.
1825	7	13,100
1826	7	15,756
1828	12	25,168

Advancing to the year 1839, when Mr. David Mushet made his inquiry, the production of Great Britain was 1,248,781 tons, there being at that period 20 furnaces in North Wales, of which 13 were in blast, making 33,800 tons of pig iron, giving an average of 2,600 tons per furnace.

Mr. Porter,† in the year 1840, gave the make of North Wales as 26,500 tons, and the make of the kingdom the same year, 1,396,400 tons. Again, in 1847, a return to Parliament gives the number of furnaces in North Wales as 11, of which 5 were active, producing 16,120 tons of pig iron; the details are as under:—

Works.	Furnaces.	Pig Iron Made.
	Nos.	Tons.
Brymbo	2	6,240
British Company . . .	1	5,200
Coed Talon	1	1,560
Plasissa	1	3,120
Total . . .	5	16,120

* For details see Appendix II., p. 834.

† "Progress of the Nation," by G. R. Porter, F.R.S.

The total make of pig iron in the kingdom the same year was 1,999,568 tons, the make of 433 furnaces. In the year 1852 the production increased to 2,701,000 tons. The only works of which we have any account at this period in North Wales are those of Brymbo, with two furnaces, and Ruabon, with three furnaces. Advancing to the year 1854 the resources of production had greatly increased, there being at that date 7 works in North Wales, with an aggregate of 11 furnaces, 9 of which were active, producing 32,900 tons of pig iron, giving an average of 3,633 tons per furnace. The works and companies in 1854 were as follows:—

Name of Works.	Owners.	Furnaces.	
		Built.	In Blast.
		Nos.	Nos.
Brymbo	The Brymbo Co.	2	2
Coed Talon	Oakley & Co.	1	0
Ffrwd	Sparrow & Co.	1	1
Leeswood	Oakley & Co.	2	1
Ruabon	New British Iron Co.	3	3
Plasissa	Samuel Gilkes	1	1
Plaskynaston	Moss and Luker	1	1
	Total	11	9

In Great Britain at this period the total production of pig iron amounted to 3,069,838 tons, the make of 555 furnaces, of which 307 were in England, 130 in Wales, and 118 in Scotland. The details are as under:—

Districts.	Quantities.
	Tons.
Northumberland, Durham, and North Yorkshire	275,000
Cumberland and Lancashire	20,000
Yorkshire (West Riding)	73,444
Derbyshire	127,500
Staffordshire	847,600
Shropshire	124,800
Gloucestershire	21,990
North Wales	32,900
South Wales	750,000
Scotland	796,604
Total production in 1854	3,069,838

In subsequent years the number of furnaces built and in blast in North Wales, with the make of pig iron, and the average make per furnace, will be found in the annexed table:—

Year.	Furnaces.		Make of Pig Iron.	Average per Furnace.
	Built.	In Blast.		
	Nos.	Nos.	Tons.	Tons.
1855	11	8	31,420	3,927
1856	10	9	47,682	5,298
1857	14	6	37,049	6,174
1858	13	6	28,150	4,692
1859	13	6	26,980	4,496
1860	14	8	49,360	6,142
1861	12	5	46,658	9,331
1862	13	5	31,719	6,344
1863	13	7	51,076	7,296
1864	14	8	51,108	6,388
1865	14	7	51,874	7,410
1866	10	5	25,515	5,103
1867	9	5	32,843	6,568
1868	9	4	37,046	9,261
1869	8	6	38,530	6,421
1870	8	6	42,695	7,116
1871	8	5	41,893	8,378
1872	8	4¾	41,464	8,728
1873	9	5	42,773	8,554
1874	9	6	51,868	8,644
1875	9	6	55,099	9,183
1876	11	4	32,723	8,181
1877	11	3½	26,715	7,630
1878	11	3	23,091	7,697
1879	11	3	18,953	6,317
1880	10	7	57,812	8,259

The above returns in the years 1874 and 1875 include the production of the Mostyn Coal and Iron Co., Flintshire, who have two furnaces, which were in blast in those years, and continued in operation till March, 1876, since which date they have been standing. The yield of the Mostyn Works in 1872 and 1873 was respectively 13,228 tons and 24,690 tons, which are included in the above returns for those years. The works and furnaces in North Wales in the year 1880 were as follows :—

No.	Name of Works.	Owners.	Furnaces.	
			Built.	In Blast.
			Nos.	Nos.
	Denbighshire—			
1	Brymbo	Brymbo Iron Co.	3	2
2	Ffrwd, Wrexham . . .	James Sparrow & Son . . .	3	2
3	Ruabon	New British Iron Co. . . .	2	1
	Flintshire—			
1	Mostyn	Mostyn Coal and Iron Co., Lim. .	2	2
	Total of Denbighshire and Flintshire .		10	7

Malleable Ironworks.—There are five of these establishments in North Wales, situated at Ruabon and Wrexham, in Denbighshire, possessing considerable resources for the manufacture of the various forms of iron. The works of the New British Iron Co., at Ruabon, contain 34 puddling furnaces and 4 rolling mills; the Broughton Hall Works, near Wrexham, 10 furnaces and 2 rolling mills; the Pontysylle Works of Messrs. Hyde, Jones and Mackay, 13 furnaces and 1 rolling mill; the Stansty Works of Messrs. Forrest and Co., 6 furnaces and 1 mill; and the Llay Hall Works at Ruabon, where fire-bricks are also manufactured. When in active operation it is estimated that the consumption of coal would not be less than from 60,000 to 70,000 tons per annum. For some years past much inactivity has prevailed in these works, and the returns for 1880 show that all were standing except the Ruabon Works of the New British Iron Company, which establishment had 13 puddling furnaces in operation out of a total of 30, and 4 rolling mills, the consumption of fuel probably not exceeding 16,000 tons of coal.

Coal and Iron Ore used in Manufacture.—It appears, on the authority of Mr. G. R. Porter,* that the coal used in 1840 in the make of 26,500 tons of pig iron in Denbighshire was 110,000 tons, giving an average of 4 tons 3 cwt. to each ton of pig iron made.

In the year 1872 and since, the quantities of coal and ore used in the works in North Wales in pig iron manufacture were as under:—

Year.	Pig Iron.	Coal Used.	Iron Ore Used.
	Tons.	Tons.	Tons.
1872	41,464	185,000	...
1873	42,773	187,278	143,973
1874	51,868	140,942	127,023
1875	55,099	144,652	139,540
1876	32,723	83,188	66,385
1877	26,715	59,669	51,717
1878	23,091	48,249	47,234
1879	18,953	35,804	39,500
1880	57,812	139,328	130,676

An examination of the above returns for the years 1872 and 1873 shows a consumption of upwards of 4 tons of coal to each

* "Progress of the Nation."

ton of pig iron made. In 1875 it did not exceed 50 cwt. of coal and 51 cwt. of iron ore in the Denbighshire furnaces, while in the Flintshire Works at Mostyn, where hematite chiefly was smelted, the average did not exceed 41 or 42 cwt. of coal and ore to each ton of pig iron made. The ores employed include argillaceous ores of the district Pottery Mine, North Staffordshire, hematite from Lancashire and Spain, and Northampton ore.

The proportion of coal and ore used in 1880 to each ton of pig iron made was respectively 49 cwt. of coal and 45 cwt. of ore, compared with 50 cwt. of coal and 51 cwt. of ore in 1875; while in recent years it appears that hematite ores have been more extensively employed than formerly.

CHAPTER XV.

SOUTH WALES AND MONMOUTHSHIRE IRON INDUSTRIES.

Ironstones of the Coal Measures—Order of Occurrence—Description and Analyses—Iron Ore Deposits of the Carboniferous Limestone, Whitchurch, Mwyndy, Hendy, and Wenvoe—Production and Analyses—Pig Iron Manufacture—Early History—Monmouthshire, Brecknockshire and Glamorganshire—Account of Cyfarthfa Works—Anthracite Pig Iron—Early History—Production of Pig Iron in Bituminous and Anthracite Coal districts since 1855—Mills and Forges and Bessemer Steel Works and Coal employed—Coal and Iron Ore used in Pig Iron Manufacture in South Wales.

The Clay Ironstones. — Formerly the ironworks of South Wales depended almost entirely upon the clay ironstones of the coal measures (argillaceous carbonates of iron): these in recent years have become more expensive to raise, as they recede further from the outcrop. At one period two-thirds of the ironstone used in the blast furnaces of Great Britain were obtained from the coal measures, now the quantities do not exceed one-third of all the ironstone raised in the kingdom.

The late Mr. Samuel Blackwell, of Dudley,* in his report of the iron ores of the kingdom, divides the South Wales coal-field into several districts, in each of which, sections are given distinguishing the strata, the seams of coal, and measures of ironstone, and the principal iron-works. The districts are enumerated as follows:—

The Eastern Outcrop.
The North-Eastern Outcrop.
The Northern Outcrop.
The Central Anticlinal District.
The Western or Anthracite District.
Southern Outcrop.

Eastern Outcrop.—In the district on the eastern edge of the coal basin, the ironstone measures hitherto wrought are at Blaenavon, known as the "Soap Vein Mine," 6 inches thick, and in

* Catalogue of the Great Exhibition of 1851, Vol. I., p. 150.

descending order, the "Black Pins," "The Three-quarter Balls," the "Meadow Vein Mine," or Pwl Llaca, and two others of less importance, known as the "Spotted Vein Mine," and the "Bottom Vein Mine." It may be observed that these measures rarely exceed 5 or 6 inches in thickness, and that they are richer in metallic iron on the east, and become less so on the west, although the measures increase in thickness in that direction.

North-Eastern Outcrop.—In this district a great development of the ironstone measures appears; at Coalbrook Vale occurs the "Soap Vein Mine," a measure of four courses, equal to 7 inches, and yielding an average of about 2,000 tons of ironstone per acre. Below occurs a vein of black band very locally distributed and not generally worked. The "Soap Vein" coal, a seam of 15 inches, intervenes between the "Black Band" seam and the "Black Pins" ironstone. This measure consists of ten irregular courses of nodules in about 15 feet of ground, and yields of ironstone about 4,500 tons per acre. Next in descending order occurs the "Elled Coal," 3 feet 4 inches thick, and the "Big Vein Coal," 5 feet 6 inches thick. The next measure, the "Three-quarter Balls," consisting of three courses, two of which are irregular, yield an average of about 1,200 tons per acre, the measure reposing on the "Three-quarter Coal," with which it is worked. The coal seams below are as follows; the

	Ft.	In.
Bwdellog Coal	2	10
Engine Vein Coal	3	2
Yard Coal	3	8

Below is the Old Coal, 5 feet 6 inches thick, with which it is worked, a measure of black band of good quality but limited in area, and regarded as an important measure in the neighbourhood of Beaufort and Nanty-Glo.

The succeeding measures in the district before the bottom coal is reached are the "Spotted Pins," at Coalbrook Vale, consisting of two courses of 4½ inches in 4 feet of ground, yielding about 1,200 tons per acre. The "Little Pins," Nanty-Glo, of two courses, equal to 5 inches in 3 feet of ground, and yielding about 1,400 tons. The "Red Vein," at Coalbrook Vale, of three courses, equal to 6½ inches, and yielding 1,800 tons per acre. The lowest measure in this section, at Nanty-Glo, known as the "Big Vein," and worked with the Bottom Coal, consisting

of two courses, equal to 6 inches, and yielding per acre about 1,700 tons.

The beds of coal in this division of the coal-field are all bituminous, while those of the ironstones are principally argillaceous; but some important beds of black band, or carbonaceous ironstone, are also worked.

Northern Outcrop.—A well defined section of the measures at Dowlais, from the "Gwrid Mine," at the top of the series, to the "Bottom Rosser Mine," exhibits a thickness of about 320 yards. It is remarked by Mr. Blackwell in this section, that in the last 100 yards there are five workable beds of coal, varying from 2 feet to 9 feet thick, and 62 distinct courses of ironstone, varying from 1 to 5 inches thick, many of which, hovever, are not necessarily worked. The measures of coal and ironstone succeed, each in descending order, as follows:—

SUCCESSION OF STRATA.

Gwrid Mine.

Soap Vein.—Three courses, equal to 6 inches and worked with Soap Vein Coal.

Upper Black Pins.—Three courses, equal to 4 inches.

Lower Black Pins.—One course, equal to 3 inches.

Yard Coal, 3 ft. 6 in.

Upper Four-foot Coal, 3 feet.

Dowlais Big Coal, 8 feet.

Black Pin Soap Vein.—Five courses, equal to 11 inches, about seventeen yards beneath Big Coal.

Ras Las Coal, 7 ft. 9 in.

Brass Vein Mine.—Two courses, 3½ inches, lying immediately on Brass Vein Coal.

Brass Vein Coal, 2 feet.

Little Pins.—Eight courses, equal to 16 inches.

Three Coals, 3 feet.

Little Vein.—One course, equal to 5 inches lying over Little Vein Coal.

Little Vein Coal, 3 feet.

Big Blue Vein.—Three courses, equal to 8½ inches, lying 4 feet above Lower Four-foot Coal, 9 ft. 3 in.

Spotted Vein.—Three courses, equal to 13 inches, in 8 feet of ground, and lying about 5 yards below Lower Four-foot Coal.

Red Vein.—Four courses, equal to 11½ inches, in 8 feet of ground, and about five yards underneath "Spotted Vein."

Little Blue Vein.—Six courses, equal to 14 inches, in about 12 feet of ground.

Jenkin Pins.—Eight courses, equal to 12 inches, in about 10 feet of ground.

Lumpy Vein.—Three courses, equal to 6½ inches, in about 6 feet of ground, and worked with Lumpy Vein Coal, 1 ft. 3 in.

Top Rosser Mine.—One course, equal to 5 inches.

Bottom Rosser Mine.—Three courses, equal to 8 inches, in about 5 feet of ground.

In the district of the above section are established the important ironworks of Dowlais, Cyfarthfa, Aberdare, Rhymney, Gadlys, and others.

Central Anticlinal District.—In the neighbourhood of Llynvi and Cwm Avon occur two important seams of black band, the upper consisting of one course, equal to 20 inches, and worked also at Maesteg; while the lower black band consists of one course of 12 inches. These beds are about 22 yards apart, and for extent of area and general quality are the most important black bands in the South Wales coal-field. At Cwm Avon the black band averages 7 inches, while at Oakwood, the same measure attains a thickness of 22 inches. The coal and mine vein at the bottom of the Llynvi section has a thickness of 27 inches, and between it and the upper black band intervene some 13 seams of coal, varying from 16 inches to 7 feet, besides numerous measures of ironstone; some of the measures at the outcrop being dug in patches or open works.

In the Cwm Avon series the total thickness of the section from the Wernddu Seam to the Lower Four-foot Seam is about 800 yards, in which occur 19 seams of coal, varying from 14 inches to 9 feet, and 10 distinct courses of ironstone.

Western or Anthracite District. — The following section presents clearly the order of occurrence and the thickness of the more important ironstone measures in the Ystalyfera and the Ywiscedwin districts, where the beds of coal are exclusively anthracitic:—

SUCCESSION OF STRATA.

	Ft.	In.
Blackband, Ystalyfera.—Fourteen inches thick, very local; yields about 2,750 tons per acre.		
Black Pins, Ystalyfera.—Two courses, equal to 8 inches; yields about 2,400 tons per acre.		
Soap Vein, Ystalyfera.—Three courses, equal to 10 inches; yields about 2,750 tons per acre.		
Soft Vein Coal.		
Penny-Pieces, Ystalyfera.—Three courses, with scattered balls; yields about 3,600 tons per acre.		
Penturin Coal	3	0
White Pins, Ystalyfera.—Sometimes called Coedfalda Mine; four courses, about 16 inches, in 14 feet of ground; yields about 4,800 tons per acre.		
White Vein Coal	1	6
Black Vein Mine, Ystalyfera.—Two courses, equal to 8 inches; yields about 2,400 tons per acre.		
Black Vein Coal	4	0

SUCCESSION OF STRATA (*continued*).

	Ft.	In.
Little Vein Mine, Ystalyfera.—Ten courses, in 18 feet of ground, got with Little Vein Coal; yields 7,400 tons per acre. This is the most important measure of ironstone in this district.		
Little Vein Coal	3	0
Billets, Ystalyfera.		
Harnlo Mine, Ystalyfera.—Two courses.		
Harnlo Coal	2	0
Big Vein, Ystalyfera.—Two courses, equal to 6 inches; yielding 1,800 tons per acre, when worked by level; if worked in patches 16 feet of ground, all interspersed with stone.		
Big Vein Coal	5	6
Black Vein Coal	2	0
Brass Vein, Ystalyfera.—Five courses, in 13 feet of ground; yielding 3,500 tons per acre.		
Brass Vein Coal	4	0
Three-Coal Vein	3	0
Bryalley Vein Coal	3	0
Little Brass Mine, Yniscedwyn.		
Little Brass Vein	2	0
Middle Vein Coal	2	6
Cwm Fit Mine, Yniscedwyn.—Three courses.		
Lower Vein Coal	3	0
Little Blue Vein, Yniscedwyn.		
Big Blue Vein ,,		
Gnappog Mine ,,		
Pin Mawr Mine ,,		

In reference to the measures of the above series Mr. Blackwell remarks, that they bear the appearance of having been subjected to an extremely high temperature; which has been, in all probability, the cause of the conversion of its beds of coal into anthracite.

Southern Outcrop.—A remarkable series of coal and ironstone measures are developed in this area of the coal-field; the following exhibit their order and thickness:—

SECTION OF STRATA.

	THICKNESS. Ft.	In.
Rock Vein	4	0
Double Vein	4	0
Little Vein	3	0
Bridge Vein	1	6
Lanthern Vein	5	0
Small Bodur Coal	5	0
Great Bodur Vein	8	0
Sooty Vein	5	6
North Vawr Vein	12	0
South Vawr Vein	4	4
Second Vawr Vein	3	0
Third Vawr Vein	5	6
Slattog Vein	2	0
Six-feet Vein	6	0

SECTION OF STRATA (*continued*).	THICKNESS. Ft.	In.
Nine-feet Balls, Cefn Cwse.—Four courses, equal to 9 inches.		
South Nine-foot Coal	9	0
Nine-feet Balls, Cefn Cwse.—Seven courses, equal to 17 inches.		
Fiery Vein Coal	4	0
Fiery Vein Ironstone, Cefn Cwse.—Six courses, equal to 14 inches.		
Five Quarter Vein	4	6
Great Gribbur Vein	6	0

Next follows an interesting section of ironstone measures at Cefn Cwse, 18 in number, before the Small Gribbur coal is reached :—

Gribbur Balls.—Two courses, equal to 6 inches.		
Upper Spotted Vein.—Two courses, equal to 4 inches.		
Spotted Balls.—Two courses, equal to 4 inches.		
Middle Spotted Vein.—Two courses, equal to 8½ inches.		
Lower Spotted Vein.—Two courses, equal to 4½ inches.		
Variegated Pin.—Two courses, equal to 5½ inches.		
Yellow Vein and Balls.—Two courses, equal to 8 inches.		
Upper Red Vein.—Two courses, equal to 3 inches.		
Upper Red Vein Balls.—Two courses, equal to 6 inches.		
Lowest Red Vein.—Two courses, equal to 4 inches.		
Pin Rhybwr Balls.—One course, equal to 3 inches.		
Black Balls.—Two courses, equal to 3 inches.		
Double Balls.—Two courses, equal to 6 inches.		
Black Pins.—One course, equal to 3 inches.		
Upper Blue Vein.—One course, equal to 4 inches.		
Blue Vein Balls.—Two courses, equal to 4 inches.		
Lower Blue Veins.—Two courses, equal to 3 inches.		
Lumpy Balls.—One course, equal to 5 inches.		
Pin Garu Balls.—Two courses, equal to 8 inches.		
Small Gribbur Coal	2	9

Analyses of the Ironstone.—The argillaceous ores of South Wales, like those of other coal-fields in the kingdom, are well represented in Mr. Samuel Blackwell's collection of iron ores previously referred to. Analyses of a large number of these have been made, and the results published in the "Memoirs of the Geological Survey," under the title of "The Iron Ores of Great Britain." From these analyses the following selection has been made, and will illustrate the composition and character of some of the important measures referred to in the several districts of the coal-field. These analyses, it should be stated, were made in the laboratory of the Royal School of Mines, under the care of Dr. Percy.

The ironstones on the eastern outcrop, at Blaenavon, known as the "Black Pins," "Three-Quarter Balls," and "Spotted Vein Mine," exhibit the following constituents, as determined by Mr. A. Dick :—

ORE DRIED AT 100° C.

Constituents.	Black Pins.	Three-quarter Balls.	Spotted Vein Mine.
Protoxide of iron	41·22	36·10	45·22
Protoxide of manganese	1·07	0·76	1·05
Alumina	0·59	0·48	0·58
Lime	2·89	1·07	1·63
Magnesia	3·38	4·52	3·04
Carbonic acid	30·07	27·33	31·58
Phosphoric acid	0·76	0·18	0·38
Sulphuric acid	trace	trace	trace
Bisulphide of iron	0·15	0·11	0·71
Water	1·21	1·06	0·66
Organic matter	0·82	0·79	0·64
Insoluble residue	17·27	27·58	14·50
Total	99·43	99·98	99·99
INSOLUBLE RESIDUE.			
Silica	11·60	19·90	9·46
Alumina	4·29	6·09	4·20
Peroxide of iron	0·45	0·60	...
Lime	...	0·35	...
Magnesia	0·30	...	0·20
Potash	0·48	0·71	0·56
Total	17·12	27·65	14·42
Metallic iron	32·44	28·55	35·48

It is further remarked that a minute trace of copper was detected in the hydrochloric acid solution of 900 grains of ore of the "Black Pins;" while minute traces of copper and lead were detected in similar solutions of 870 grains of the "Three-Quarter Balls," and 905 grains of ore of the "Spotted Vein Mine." * The word mine, it may be observed, is commonly used in South Wales for ore.

The "Black Pin Mine" (Middle Pin), Pontypool, examined by Mr. E. Riley, is thus described: "Clay ironstone, easily scratched by a steel point; colour, blackish grey; fracture, subconchoidal; surface of fracture, rough. A very thin vein of carbonate of lime occurs in the sample analysed." A distinct trace of copper was detected in 234 grains of the ore. The results appear as follows:—

* "Iron Ores of Great Britain," Part III., pp. 183, 185, 186.

RESULTS TABULATED.*—ORE DRIED AT 100° C.

Protoxide of iron	26·98
Protoxide of manganese	0·49
Alumina	1·19
Lime	3·11
Magnesia	4·13
Carbonic acid	23·40
Phosphoric acid	0·35
Silica, soluble in hydrochloric acid	0·50
Bisulphide of iron	0·52
Water in combination	0·78
Organic matter	0·82
Insoluble residue	36·51
Total	98·78

INSOLUBLE RESIDUE.

Silica	27·41
Alumina	7·69
Peroxide of iron	0·73
Lime	0·22
Magnesia	0·42
Potash	1·18
Soda	0·16
Total	37·81

This ore, as appears from the above results, is not rich in metallic iron, yielding but 21·49 per cent.; clay, after ignition, giving 26·16 per cent.

The Black Band measures of Pontypool and Abercarne, examined by Mr. W. Ratcliffe and Mr. A. Dick, the former giving the following description of the Abercarne measure: "Colour, brownish grey; compact; containing thin seams of coal and films of pyrites in some of the joints," show the annexed results. The Abercarne variety giving 36·49 per cent. of metallic iron; the Pontypool, 24·90 per cent.:—

It is observed of the Black Band, Pontypool, that the combined water could not be determined owing to the large amount of tarry matter evolved when the ore was heated sufficiently to expel the water combined with the clay. Of hygroscopic water, however, it was found that in an analysis of 47·08 grains of this ore, the loss of water at 100° centigrade amounted to 0·29 grains.

* "Iron Ores of Great Britain," Part III., p. 191.

Constituents.*	Black Band, Pontypool.†	Black Band, Abercarne.
Protoxide of iron	31·74	43·37
Sesquioxide of iron	...	4·10
Oxide of manganese	...	1·50
Protoxide of manganese	1·06	...
Alumina	7·75	6·05
Lime	3·84	3·00
Magnesia	3·51	0·25
Potash	1·12	0·32
Carbonic acid	25·03	30·50
Sulphuric acid	trace	1·56
Phosphoric acid	0·35	traces
Silica	16·97	2·80
Bisulphide of iron	0·48	...
Hygroscopic water	...	0·27
Combined water	...	0·31
Organic matter	8·50	6·25
Total	100·35	100·28

Traces of silver and copper were detected in 600 grains of the Pontypool Black Band.

North-Eastern Outcrop.—The ironstones of this district are well represented in the measures worked at the Cwm Celyn and Blaina Ironworks in Monmouthshire. The principal ironstones, taken in ascending order, in the section, are as follows:—Red Vein, Spotted Vein, Black Pins, and Soap Vein.† The analyses were made as far back as the year 1860 by Dr. Noad, F.R.S., for Messrs. Levick and Simpson, the then proprietors of the above-named ironworks.

It is observed in reference to the constituents of these measures that "Metallic sulphides are very unusual in the ironstones of this eastern extremity of the coal-field, remarkably so as compared with the ironstones of central England." On the other hand, these measures frequently contain quartz, and, more rarely, but yet in comparative abundance, Hatchettine and Millerite, or sulphide of nickel, substances not observed in the analogous deposits of our midland and northern coal-fields.

* Iron Ores of Great Britain, Part III., pp. 192–3.

† For detailed section of these measures, see page 193 of the "Iron Ores of Great Britain;" where also will be found descriptive notes on the ironstones of this and surrounding districts by Mr. W. Smyth, F.R.S.

Tabulated Results of Analysis.	RED VEIN MEASURES.			
	Red Vein.	Black Vein.	"Jack" in Red Vein.	Grey Vein.
Silica	8·31	4·600	8·130	15·240
Alumina, insoluble in hydrochloric acid	3·13	2·000	2·220	3·300
Alumina soluble in hydrochloric acid	2·52	3·600	5·150	2·700
Carbonate of iron	73·79	80·220	51·120	70·500
Carbonate of lime	2·95	4·650	19·800	1·980
Carbonate of magnesia . . .	3·80	2·910	11·880	3·000
Protoxide of manganese . .	0·92	1·020	*	*
Phosphoric acid	0·53	0·427	*	0·217
Sulphuric acid	traces	trace	*	trace
Bisulphide of iron	0·17	0·123	*	0·119
Potash	0·48	*	*	*
Organic matter and water . .	2·36	*	*	*
	98·96	99·550	98·300	97·956
Loss by roasting	24·00	30·700	30·40	28·00
Metallic iron	35·625	38·75	24·65	34·00

Tabulated Results of Analysis.	BLACK PIN MEASURES.			SOAP VEIN MEASURES.	
	Black Pin.	Red Pin.	Yellow Pin.	Top Soap Vein.	Bottom Soap Vein.
Silica	12·000	15·400	25·200	20·000	9·540
Alumina insoluble in hydrochloric acid.	4·000	5·000	8·200	5·000	4·460
Alumina soluble in hydrochloric acid	1·150	3·520	8·200	2·850	2·500
Carbonate of iron . .	71·700	57·990	48·300	59·610	77·340
Carbonate of lime . .	2·640	3·450	1·200	4·500	...
Carbonate of magnesia .	4·230	8·580	6·000	4·800	0·900
Protoxide of manganese	1·420	0·640	0·327	...	0·530
Phosphoric acid . .	0·482	0·750	0·214	0·424	0·576
Sulphuric acid . . .	trace	trace	trace	trace	trace
Bisulphide of iron . .	trace	0·241	0·124	0·246	0·192
Potash	0·489	0·450	0·389	0·444	0·530
Organic matter and water	1·645	2·340	1·320	1·442	2·240
	99·756	98·361	99·474	99·316	98·808
Loss by roasting . .	28·00	26·80	22·70	25·20	29·90
Metallic iron . . .	34·60	28·00	23·30	28·75	37·30

The following ironstones worked in the Blaenavon district, and employed at the Blaenavon Ironworks,* by Messrs. Thomas, exhibit the annexed results. They are thus described:—

1. *Black Pins.*—A nodular form of clay ironstone, having cracks of contraction partly filled with a white crystalline substance, composed of the carbonates of iron, lime and magnesia.

2. *Pwl Llaca.*—A clay ironstone, brownish grey in colour, and homogeneous. The seam measures 2½ inches barely.

3. *Bottom Vein.*—A clay ironstone, light brownish grey in colour, homogeneous. The seam measures 3 inches.

4. *Ball Mine.*—Brownish grey clay ironstone, containing a few very thin seams of limespar.

5. *Grey Vein.*—A clay ironstone, brownish grey in colour, with very rough surface of fracture. The seam measures 2 inches.

Constituents.	Black Pins.	Pwl Llaca.	Bottom Vein.	Ball Mine.	Grey Vein.
Protoxide of iron	47·02	47·60	42·04	51·28	39·80
Oxide of manganese	1·00	0·46	0·87	1·11	1·17
Lime	2·57	0·77	1·03	0·78	2·41
Magnesia	3·23	2·30	2·51	0·53	3·30
Carbonic acid	34·30	32·90	29·52	33·32	30·04
Phosphoric acid	0·92	0·71	0·90	0·74	1·02
Bisulphide of iron	0·25	0·08	0·06	0·06	0·05
Water hygroscopic	0·34	0·32	0·36	0·18	0·54
Water in combination	1·58	1·28	2·00	1·67	2·12
Organic matter	0·40	0·30	0·30	0·35	0·45
Clay ignited	8·63	13·60	20·87	10·33	19·40
	100·24	100·32	100·46	100·35	100·30
Metallic iron	36·77	37·32	33·20	40·12	31·45

The Northern Outcrop.—A series of the ironstones raised and smelted at the extensive ironworks at Dowlais,† Merthyr Tydfil, was analysed for the proprietors by Mr. Edward Riley, who has determined the constituents of the following measures:—

The Dowlais Rosser Vein Mine.—This ironstone is above the Lower Rosser Vein, and occurs in balls, with a very stony appearance and fracture. The sample was taken as an average:—

* See return to House of Commons, "Cast Iron Experiments," report made to War Office, 29th July, 1858, p. 148.

† See for detailed section the "Iron Ores of Great Britain," p. 200.

SOLUBLE IN ACIDS.

	GRAINS.
Silica	0·27
Protoxide of iron	41·03
Alumina	0·23
Protoxide of manganese	0·55
Lime	2·83
Magnesia	3·11
Carbonic acid	28·49
Moisture	0·57
Combined water	1·36
Phosphoric acid	0·70
Organic matter	0·07

INSOLUBLE IN ACIDS.

Silica	13·08
Alumina	5·56
Peroxide of iron	0·41
Lime	0·17
Magnesia	0·25
Potash	0·86
Total	99·54
Metallic iron	32·18

The Dowlais Spotted Vein Mine.—This measure consists of three bands of ironstone, but that to which the analysis refers is only the lower band, consisting of large balls or roundish nodules, termed "riders," which sometimes amount to 10 or 12 inches in thickness. They are often very cavernous, and exhibit in abundance crystals of quartz, carbonate of iron, and millerite, or sulphide of nickel. The yield of metallic iron of this measure is, in the calcined state, 53·6 per cent. Its constituents are as follows:—

RESULTS TABULATED.

Silica	8.38
Alumina	5·79
Peroxide of iron	76·61
Red oxide of manganese	1·21
Lime	3·13
Magnesia	3·96
Phosphoric acid	0·57
Potash	0·87
Sulphur	0·06
Total	100·58

Another measure, the "Gŵr Hyd Mine," is of considerable value, the top vein of which is argillaceous, described as a "hard stone of a brownish hue and with granular fracture. The bottom vein of this Gŵr Hyd Mine is a black band ironstone containing sufficient carbonaceous matter to effect its calcination without the

aid of additional fuel. The top and bottom veins of the Gwr Hyd Mine yield as follows:—the first named giving of metallic iron 30·33 per cent., increased in the bottom or black band vein, to 37·80 per cent.

Central Anticlinal District.—The ironstones of this district are illustrated by analysis of the Sulphury Mine, Cwm Avon. This measure occurs between the Finery and the Sulphury seams of coal, and enjoys a high repute as a good ore. It consists of three courses averaging about 7 inches in thickness together. The top vein is a rough granular stone, of blackish grey tint, showing, on fracture, vertical lines of carbonate of lime and iron. The middle is very similar, showing also occasional crystals of blackish quartz in the cavities. The bottom vein is more compact, and breaks with irregularly angular fracture.

RETURNS TABULATED.—ORE DRIED AT 100° C.

Protoxide of iron	40·30
Protoxide of manganese	1·03
Alumina	1·43
Lime	1·44
Magnesia	2·77
Carbonic acid	28·23
Phosphoric acid	0·88
Sulphuric acid	trace
Bisulphide of iron	0·09
Water	0·74
Organic matter	0·29
Insoluble residue	22·48
Total	99·68

INSOLUBLE RESIDUE.

Silica	14·43
Alumina	6·47
Peroxide of iron	0·34
Magnesia	0·17
Potash	0·82
Total	22·23

The metallic iron amounted to 31·63 per cent., and a trace of copper was detected in 800 grains of the ore.

The above analysis, and the following, in the Western district, were made by Mr. A. Dick, who describes the "White Pins," Ystalyfera, sometimes called the Coedfalda Mine, as follows:—"This measure consists of balls and pins, or roundish nodules and flat courses; although called white they are generally of a dark grey colour, and have frequent cracks, filled with carbonate of lime

and iron, which in the iron fracture give a vertical lenticular section:—

RESULTS TABULATED.—ORE DRIED AT 100° C.

Protoxide of iron	29·34
Protoxide of manganese	0·73
Alumina	0·96
Lime	0·84
Magnesia	5·63
Carbonic acid	24·56
Phosphoric acid	0·14
Sulphuric acid	trace
Bisulphide of iron	0·08
Water	1·00
Organic matter	0·33
Insoluble residue	35·73
Total	99·34

INSOLUBLE RESIDUE.

Silica	24·98
Alumina	9·75
Peroxide of iron	0·53
Magnesia	0·20
Potash	1·00
Total	36·46

The metallic iron in this ore is equivalent to 23·22 per cent.; a trace of lead being detected in 910 grains of the ore.

Another clay ironstone of the Ystalyfera district, known as the "Cheese Mine," published in the "Returns of Cast-Iron Experiments" previously referred to, is thus described: "The sample from which an average was selected for analysis, consisted of a nodule of clay ironstone, dark grey in colour, and intersected by numerous veins of calcareous iron spar, in which a few crystals of quartz were discovered."

RESULTS TABULATED.

Peroxide of iron	42·72
Oxide of manganese	0·46
Lime	4·66
Magnesia	5·73
Carbonic acid	35·70
Phosphoric acid	0·40
Bisulphide of iron / Silica, as quartz	traces
Water hygroscopic	0·26
Water in combination	1·54
Organic matter	0·30
Clay ignited	8·23
Total	100·00

The metallic iron contained in the above was equivalent to 33·45 per cent.

The annexed summary exhibits, at a glance, the amount of metallic iron contained in those measures of the South Wales coal-field contained in the foregoing analyses, and others:—

Ironstones.	Analyst.	Metallic Iron.
Monmouthshire—		
Spotted Veins, Blaenavon	A. Dick . .	35·48
Three-quarter Balls, ,, ...	,, . .	28·55
Black Pin, ,, ...	,, . .	32·44
Spotted Vein Balls, Pontypool . . .	E. Riley . .	34·96
Meadow Vein, ,, . . .	A. Dick . .	26·01
Three Cakes, ,, ...	,, . .	20·95
Black Pin, ,, . . .	E. Riley . .	21·49
Black Band, ,, ...	A. Dick . .	24·90
,, Abercarne	W. Ratcliffe .	36·49
Red Vein, Cwm Celyn	Dr. Noad . .	35·62
Black Vein, ,, ...	,, . .	38·75
"Jack" in Red Vein, Cwm Celyn . .	,, . .	24·65
Grey Vein, ,, . . .	,, . .	34·00
Black Pin, ,, ...	,, . .	34·60
Red Pin, ,, . . .	,, . .	28·00
Yellow Pin, ,, ...	,, . .	23·30
Top Soap Vein, ,, . . .	,, . .	28·75
Bottom Soap Vein, ,, ...	,, . .	37·30
Glamorganshire—		
Rosser Vein, Dowlais	E. Riley . .	32·18
Spotted Vein, ,, ...	,, . .	53·60*
Welsh Little Vein, ,, ...	,, . .	30·43
Welsh Lumpy, ,, ...	,, . .	34·72
Gŵr Hyd Mine, ,, ...	,, . .	30·33
Black Band, ,, ...	,, . .	37·80
Sulphury Mine, Cwm Avon	A. Dick . .	31·63
White Pins, Ystalyfera	,, . .	23·22
Cheese Mine, ,, ...	F. A. Abel .	33·45
Black Band Lower, Llynvi†	...	36·08
Black Band Lower, ,, ...	...	36·80
Black Band Upper, ,, ...	...	31·36
Pembrokeshire—		
Catshole, Saundersfoot	W. Ratcliffe .	26·39
Kilvelgy, ,, ...	,, . .	29·15

Production of Ironstone.—There does not appear to exist any reliable information before the year 1857. Occasional returns for a few districts are met with, but they fail to represent anything like the yield of the ironstone measures of South Wales. For

* In calcined stone.

† Used extensively for making iron in the Llynvi and Maesteg districts.

1857, however, there appears a return amounting to 1,013,941 tons of argillaceous ironstone, and a further quantity of 24,300 tons of brown hematite, also raised in the South Wales area from the carboniferous limestone and Permian series, to which attention will be called further on. The production of 1857 appears in the annexed details:—

COUNTY.	DISTRICT.	QUANTITY. Tons.	QUANTITY. Tons.
Monmouth,	Abersychan	43,098	
,,	Blaenavon	80,111	
,,	Blaina } Coalbrook Vale } Cwm Celyn }	73,207	
,,	Ebbw Vale	37,567	
,,	Pontypool	41,200	
,,	Sirhowey	65,886	
,,	Tredegar	86,182	
,,	Varteg and Golynos	56,133	
,,	Varteg Hill	60	
,,	Victoria	15,852	
	Total of Monmouth	———	499,296
Brecknock,	Beaufort	74,600	
,,	Clydach	34,000	
	Total of Brecknock	———	108,600
Glamorgan,	Aberamman	32,812	
,,	Dowlais	145,036	
,,	Gadly's	17,468	
,,	Llynvi	49,481	
,,	Maesteg	65,000	
,,	Penydarren	80,617	
,,	Tondu	15,631	
	Total of Glamorgan	———	406,045
	Total of South Wales		1,013,941

Again, for the year 1858, the production was 752,231 tons, of which 24,635 tons were brown hematite, raised at Llantrissant, Mwyndy and Wenvoe. Regarding the value of these and other iron ores employed in the ironworks on the eastern edge of the coal basin in Monmouthshire at that time, the following were the prices of the several varieties delivered at Newport, per ton:—

COUNTY.	IRON ORE.	s.	d.
Devonshire,	Brixham	13	0
,,	Prawle	13	0
Somersetshire,	Honeymead	10	0
,,	Ashton Vale	10	0
South Wales,	Argillaceous	11	0
,,	Llantrissant (Brown Hematite)	15	0

The charge of conveyance from Newport to the ironworks varying from 2*s.* 3*d.* to 2*s.* 6*d.* per ton. It need scarcely be said that the ironstone obtained annually in South Wales is totally inadequate to the requirements of the blast furnaces; on the other hand, the abundance of fuel enables the ironmaster to increase his supplies by importing rich and valuable ores from the hematite districts of Cumberland, Lancashire, the Midland and South-Western districts of England, bearing a high rate of carriage, and he is further in a position to supply his wants by the favourable geographical situation of the district, which enables him to import ores from Spain and other foreign countries.

Since 1859 the production of clay ironstone in South Wales has been as follows:—There is every reason to believe, however, that these figures fall short of the actual quantities raised; this conclusion is arrived at by a comparison of the annual yield of the blast furnaces, for which reliable data exist in the quantities of the ores employed and their yield of metallic iron:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1859	649,758	1870	560,005
1860	630,705	1871	969,714
1861	545,705	1872	1,247,594
1862	472,053	1873	943,926
1863	420,017	1874	661,616
1864	468,355	1875	*495,840
1865	387,742	1876	476,285
1866	368,692	1877	367,316
1867	501,186	1878	318,399
1868	712,680	1879	299,000
1869	715,001	1880	278,361

The value of these ores in 1872 averaged 12*s.* per ton; while during the year 1878 the price did not exceed 10*s.* per ton. The production of ironstone in South Wales in the year 1880 amounted to 278,361 tons, of the value of £139,180, or 10*s.* per ton.

Iron Ore Deposits of the Carboniferous Limestone.—At Whitchurch, near Cardiff, in Glamorganshire, and at Pentyrch, at the mouth of the Taff Valley, deposits of brown hematite occur at the base of the carboniferous limestone, in nearly vertical

* In the above return till 1875 are included the hematite ores raised in Wales, after 1875 the quantities above include clay iron ores only.

fissures in the limestone, with an underlay of from 3 to 7 degrees south. The ore wrought at Pentyrch has been extensively employed in the works of the same name, in the manufacture of sheet iron and tin plates, and has long enjoyed the reputation of being amongst the best brands in the kingdom.

Again, in the lower bed of the Permian series, brown hematite ore exists. These deposits occur locally in hollows or basins; these basins at Mwyndy, near Llantrissant, assume wedge-like shapes at the outcrop, the ore occurring in hollows in the upturned edges of the underlying rocks. Similar ore is also wrought at the Bute Mine, near the same place. Another deposit exists west of Llantrissant, at Quay-Coch, two miles north of Porth Cawl, where it lies over the carboniferous limestone, having a thickness of five feet.

Of the hematite ore raised in Glamorganshire the following gives the production in each of the years named. Formerly hematite was wrought to a limited extent at Hendy and Wenvoe, and recently at Llwynsaer by the Mwyndy Iron Ore Company.

The ore raised at Llwynsaer in 1880 amounted to 12,315 tons, of the value of £6,773.

Year.	Mwyndy.	Bute.	Garth.	Total.
	Tons.	Tons.	Tons.	Tons.
1858	12,500	...	...	12,500
1860	29,217	...	...	29,217
1862	27,260	16,633	...	43,893
1864	50,401	13,168	...	63,569
1866	41,387	26,000	...	67,387
1868	60,660	22,875	...	83,535
1870	66,191	22,530	...	88,720
1871	58,723	24,601	...	83,324
1872	49,661	23,105	...	72,766
1873	52,816	339	...	53,155
1874	68,787	36,558	15,545	120,890
1875	67,697	16,057	16,536	100,290
1876	61,618	8,525	13,421	*83,970
1877	49,084	7,581	9,861	†77,320
1878	30,451	8,375	7,828	‡56,639
1879	20,986	985	6,695	§53,811
1880	43,095	191	9,966	‖65,567

* Including 405 tons raised at Rudry.
† Including 10,794 tons raised at Llwynsaer.
‡ Including 9,894 tons raised at Llwynsaer and Trecastle.
§ Including 20,986 raised at Trecastle.
‖ Including 12,315 tons raised at Llwynsaer.

The value of these hematite ores for some years past shows little variation, the average price being from 12*s*. to 14*s*. per ton.

The mines raising hematite ore in South Wales, their situation, proprietors, and chief agents are as follows during the year 1880:—

No.	Name of Mine.	Situation.	Name of Proprietor or Company.	Name of Manager or Agent.
1	Bute Hematite .	Llantrissant . .	Dowlais Iron Co. . . .	John Powell.
2	Llwynsaer . .	" . .	Mwyndy Iron Ore Co., Lim. .	William Vivian.
3	Mwyndy and Trecastle	" . .	" " " . .	David Evans.
4	Melyn Griffith .	Cardiff . .	T. W. Booker & Co., Lim. .	E. D. Howell.
5	Garth . . .	" . . .		

Analyses of these Iron Ores.—The ore raised at Mwyndy, near Llantrissant, is thus described by Mr. W. Ratcliffe: "Compact hematite; easily scratched by a file; lustre, earthy; colour, deep red yellow; streak, brown red; fracture, uneven, showing numerous cavities lined with crystals of quartz; the ore contains minute particles of quartz, visibly diffused through it. Some specimens selected from large solid masses of the ore are scarcely scratched by a file; colour, bright purple blue. Particles of quartz are diffused through these, and are only plainly visible by the aid of the microscope. The samples analysed were composed of a mixture of these varieties."

RESULTS TABULATED.

Sesquioxide of iron	70·572
Oxide of manganese	0·522
Silica	18·362
Alumina	1·572
Lime	3·562
Magnesia	1·311
Potash	0·317
Sulphuric acid	0·451
Phosphoric acid	0·132
Carbonic acid	1·716
Water	0·660
Total	99·177

The total amount of metallic iron contained in this ore is equivalent to 48·934 per cent.; it further appears that a trace of cobalt was detected in 300 grains of the ore.

The calcareous hematite of Whitchurch, also examined by

Mr. W. Ratcliffe, gives the following results. The ore is thus described:—"Compact; soft; lustre, greasy to dull; colour, dark red on outside; on the fracture, blackish red; streak, bright red, soils the fingers, and makes a red streak on paper; structure, oolitic and sometimes pisolitic."

RESULTS TABULATED.

Sesquioxide of iron	66·554
Protoxide of iron	1·131
Oxide of manganese	1·127
Alumina	1·753
Lime	8·547
Magnesia	1·116
Silica	0·312
Potash	0·190
Soda	0·068
Carbonic acid	5·733
Sulphuric acid	1·309
Phosphoric acid	1·017
Organic matter	0·376
Water (total)	2·118
Ignited insoluble residue	10·356
Total	101·707

IGNITED INSOLUBLE RESIDUE.

Silica	8·589
Alumina (with a little iron)	1·042
Lime	0·850
Magnesia	0·272
Potash	0·235
Soda	0·076
Total	11·064

The total amount of metallic iron contained in this ore is equivalent to 47·468 per cent. A note appended to the analysis states,* that "No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 300 grains of ore, was detected.

The Mwyndy Company previously referred to possesses an estate at Trecastle containing some valuable deposit of iron ore; the mines are situated near the Llantrissant station and on the Cowbridge line, three miles distant from Mwyndy. Of late these deposits have not been worked except in a limited manner. The following analyses of two samples of this hematite, by Mr.

* "Iron Ores of Great Britain," Part III., p. 217.

John Pattinson, of Newcastle-upon-Tyne, show the subjoined results:—

Constituents.	Trecastle. No. 1.	Trecastle. No. 2.
Peroxide of iron	87·43	74·71
Protoxide of manganese	0·24	0·19
Alumina	0·24	1·90
Lime	0·28	5·56
Magnesia	0·27	0·94
Oxide of copper	trace	trace
Carbonic acid	...	4·90
Silica	1·97	3·86
Sulphur	0·02	0·02
Phosphoric acid	0·01	0·01
Combined water	9·29	7·64
Moisture	0·21	0·24
	99·96	99·97

The high character of these ores appears in the fact that the first gives 61·20 and the second sample 52·30 of metallic iron.

Pig Iron Manufacture.—On the northern and eastern outcrop of the South Wales mineral basin, in the shires of Monmouth and Brecknock, are established some of the oldest and most extensive iron works in the kingdom. About the year 1755 it appears that a Mr. Anthony Bacon acquired an extensive mineral property in the neighbourhood of Merthyr, for a term of 99 years, at the moderate rental of £200 per annum, and it was upon this same property in later years that many of the present iron works of the above named districts were established.

Previously, in the year 1565, it is known that a Mr. Capel Hanbury erected a charcoal blast furnace at Pontypool, which place is regarded as one of the earliest seats of the iron trade; and there is reason to believe that the Romans worked iron ore in those hills then covered with wood, as they undoubtedly did in Dean Forest, ancient heaps of slag being occasionally struck upon. In consequence of the destruction of timber for fuel being carried to a serious extent in the reign of Elizabeth, Acts were passed prohibiting the erection of iron works except in districts specified; so that in the year 1740 the aggregate yield of charcoal pig iron amounted to but 17,350 tons, the yield of 59 furnaces distributed over the kingdom as follows:—

County.	No. of Furnaces.	Charcoal Pig Iron.
		Tons.
South Wales—		
Brecon	2	600
Caermarthenshire	1	100
Glamorganshire	2	400
Monmouthshire	2	900
North Wales—		
Denbighshire	2	550
England—		
Cheshire	3	1,700
Derbyshire	4	800
Gloucestershire	6	2,850
Hampshire	1	200
Herefordshire	3	1,350
Kent	4	400
Nottinghamshire	1	200
Shropshire	6	2,100
Staffordshire	2	1,000
Sussex	10	1,400
Warwickshire	2	700
Worcestershire	2	700
Yorkshire	6	1,400
Total	59	17,350

Thus of the make of charcoal iron in the year 1740 South Wales with its seven furnaces produced 2,000 tons. Advancing to the year 1788* there appear to have been but 24 furnaces in England and Wales making charcoal pig iron amounting to 13,100 tons, and 53 furnaces making 48,200 tons of coke pig iron, the former giving an average of 545 tons per furnace, compared with 294 tons per furnace in the year 1740.

Of the production of 1788, seven furnaces were in South Wales, producing 4,300 tons of charcoal pig, and eight furnaces making 8,200 tons of coke pig iron, giving a total of 12,500 tons of pig iron, the make of fifteen furnaces in South Wales, amounting to nearly one-fourth of the total production of the kingdom at this period.

As this period marks a new era in the history of pig iron manufacture, and the more general use of coke as a reducing agent in the blast furnace, it will be a fitting place to record the quantities of charcoal, and coke pig iron produced in Great Britain, viz., for the year 1788, which were as follows:—

* "History of the Iron Trade," by H. Scrivener, 1854, p. 87.

CHARCOAL PIG IRON.

	No. of Furnaces.	Make of each Furnace.	Total.
		Tons.	Tons.
South Wales—			
Caermarthenshire . . .	1	400	400
Glamorganshire . . .	3	600	1,800
Monmouthshire . . .	3	700	2,100
England—			
Cumberland	1	300	300
Derbyshire	1	300	300
Gloucestershire . . .	4	650	2,600
Lancashire	3	700	2,100
Shropshire	3	600	1,800
Sussex	2	150	300
Westmoreland . . .	1	400	400
Yorkshire	1	600	600
North Wales—			
Merionethshire . . .	1	400	400
Total . . .	24		13,100

In the same year the make of coke pig iron in England and Wales was as follows :—

COKE PIG IRON.

	No. of Furnaces.	Make of each Furnace.	Total.
		Tons.	Tons.
South Wales			
Brecknockshire . . .	2	800	1,600
Glamorganshire . . .	6	1,100	6,600
England—			
Cheshire	1	600	600
Cumberland	1	700	700
Derbyshire	7	600	4,200
Shropshire	21	1,100	23,100
Staffordshire . . .	6	750	4,500
,, ...	3	800	2,400
Yorkshire	6	750	4,500
Total . . .	53		48,200

Scotland produced in the year 1788 from two furnaces in Argyleshire, situated at Goatfield and Bunawe, 1,400 tons of charcoal pig iron and 5,600 tons of coke pig iron, from four furnaces erected at the Carron Works in Stirlingshire, and two

furnaces erected at Wilsonstown or Cleugh, in Lanarkshire. Summarising the above returns for 1788 the result is as shown:—

Districts.		No. of Furnaces.	Pig Iron.
			Tons.
South Wales . . .	Charcoal furnace.	7	4,300
England	,, . .	16	8,400
North Wales . . .	,, .	1	400
Scotland . . .	,, . .	2	1,400
	Total . .	26	14,500
South Wales . . .	Coke Pig . .	8	8,200
England	,, . .	45	40,000
Scotland . . .	,, . .	6	5,600
	Total . .	59	53,800

Presenting a total for Great Britain of 85 furnaces and 68,300 tons of pig iron, the average yield of the English furnaces being 796 tons, compared with 875 tons, the average yield of the Scotch furnaces. The three charcoal furnaces in operation in Monmouthshire in 1788 were situated at Pontypool, Tintern Abbey, and Monmouth. Passing on to the date of the erection of coke furnaces it appears that the first furnace using coke was erected at the Sirhowey works, by the Messrs. Atkinson and Co., in 1788, and in the year 1796 produced 1,930 tons of coke pig iron. The Blaenavon works followed in the same year with three furnaces, and in the year 1796 made 4,311 tons of coke pig iron; while in the same year the works at Blaendare, near Pontypool, and the Ebbw Vale Works put their first furnaces in blast; the former in the year 1796 making 1,500 tons, and the latter 1,660 tons of coke pig iron. Other works succeeded with rapidity; those at Nantyglo were founded in 1795, Varteg in 1803, and the works at Tredegar in 1805. In Brecknockshire the Beaufort Works were laid down by the Messrs. Kendall and Evans, in the year 1780, the furnace producing in the year 1796 some 1,660 tons of coke pig iron.

Towards the close of the past century much anxiety was shown by the coal and iron masters of the kingdom at Mr. Pitt's projects to increase the revenue—the first in 1796, by a tax on coal at the pit's mouth, and the second in 1797, on pig iron of 20 shillings

per ton; considerable opposition was shown to both those measures. A committee of the House of Commons was appointed, presided over by William Manning, M.P., and the whole subject very fully considered, the result being the abandonment of both measures. The inquiry was not however barren in results, as it brought out some very important and interesting facts upon the condition of the iron works in Great Britain at this time. These were embodied in a statement prepared by Dr. H. G. McNab,* of Severn House, Shropshire, and addressed to the chairman. In this statement a complete list of all the furnaces in Great Britain appears, with the return given by the Excise of the quantity of pig iron made in the year 1796; the quantities supposed and calculated upon, by three gentlemen whose initials alone appear, and a third statement of the quantities really made. The works in operation at this period in Monmouthshire and Brecknockshire were those named in the following table:—

Names of Furnaces.	No. of Furnaces.	Excise Return.	Supposed Quantities.	Exact Return.
		Tons.	Tons.	Tons.
Monmouthshire				
Blaendare	1	1,404	1,404	1,500
Blaenavon	3	5,460	5,460	4,318
Ebbw Vale	1	1,560	1,560	397
Sirhowey	1	1,820	1,820	1,930
Total	6	10,244	10,244	8,145
Brecknockshire—				
Beaufort	1	1,560	1,560	1,660
Clydach	1	1,820	1,820	1,625
Hirwain	1	1,400	1,400	1,050
Total	3	4,780	4,780	4,335

The three sources of information are given for comparison; the exact returns however give a total production in the two districts of 12,480 tons, the make of nine furnaces, showing an average make per furnace of 1,387 tons.

This return for the year 1796 possesses so much interest as containing the detailed list of iron works existing in the kingdom, and for purposes of comparison will be so frequently referred to in subsequent pages, that the annexed table has been prepared from

* McNab on the "Coal Trade," 1801.

the original of Dr. Macnab, intending to show the number of furnaces and the make of each district in the kingdom; these were as follows:—

Districts.	No. of Furnaces.	Excise Return.	Supposed Quantities.	Exact Return.
		Tons.	Tons.	Tons.
Cumberland . . .	2	3,744	1,600	565
Derbyshire . . .	12	10,200	10,200	9,656
Gloucestershire . .	2	380	380	380
Herefordshire . . .	4	2,070	2,070	1,749
Lancashire . . .	3	2,180	2,180	2,249
Mid Wales . . .	1	200	200	150
Shropshire . . .	23	68,129	43,360	32,969
Staffordshire, North . .	2	4,700	2,200	1,959
,, South .	14	15,820	15,256	13,210
Sussex	1	172	173	173
South Wales . . .	24	38,508	39,808	34,101
Wales, North . . .	5	6,230	1,560	1,144
,, West . . .	1	1,056	1,056	290
Yorkshire, West Riding	13	13,922	13,922	10,398
Scotland . . .	15	...	17,040	15,186
,, charcoal . .	2	...	1,600	900
Total . .	124	167,311	152,605	125,079

Towards the end of the year 1800 the total number of furnaces was increased by 40, of which 21 were in blast and 19 in course of erection in Great Britain, distributed as follows:—

Districts.	In Blast.	Building.
	Nos.	Nos.
Durham	0	1
Gloucestershire	1	0
Shropshire	5	2
Staffordshire, North . . .	2	1
,, South . .	7	11
South Wales	5	4
Scotland	1	0
Total . . .	21	19

Beginning with the present century, a reliable source of information is at hand; one return in 1806, prepared by an iron-master conversant with the iron industries of the kingdom, shows the production of the Brecknockshire furnaces as 7,998 tons, and those of Monmouthshire as 22,950 tons, giving a total of 30,948 tons for both counties. From the return referred to, the annexed statement has been prepared, showing the works and furnaces in operation and details of production:—

Districts.	Furnaces.		Pig Iron Made.
	Built.	In Blast.	Tons.
Brecknockshire—			
Beaufort	2	2	4,696
Clydach	2	1	2,802
Hirwain	1	1	500
Total	5	4	7,998
Monmouthshire—			
Blaendare	1	0	...
Blaenavon	4	3	7,846
Bishop's Wood	1	1	653
Ebbw Vale	2	1	3,664
Nantyglo	2	0	...
Pontypool	1	1	600
Sirhowey	2	2	3,700
Tintern Abbey	1	1	987
Tredegar	2	2	4,500
Varteg	1	1	1,000
Total	17	12	22,950

In the same year the total production of the 161 furnaces in Great Britain amounted to 248,851 tons, being an average make per furnace of 1,515 tons. Advancing to the year 1811 there appears to have been 24 furnaces in blast in these districts, giving an average yield per furnace of 2,000 tons, or a total production of 48,000 tons of pig iron. A paper in the Edinburgh Philosophical Magazine* affords information of the production of Great Britain in the year 1827, when 284 furnaces were in operation, yielding 690,000 tons of pig iron. The general production appears to have been as follows:—

Districts.	Furnaces.	Tons.
Staffordshire	95	216,000
Shropshire	31	78,000
South Wales	90	272,000
North Wales	12	24,000
Yorkshire	24	43,000
Derbyshire	14	20,500
Scotland	18	36,500
Total	284	690,000

* "The Iron Trade of Great Britain," 1828, p. 115.

It is here shown that the yield of the South Wales furnaces gave upwards of an average make of 3,000 tons, compared with 2,000 tons in 1811, and 1,515 tons in 1806.

The Government instituted an inquiry in the year 1831, which was intrusted to Mr. F. Finch, formerly member for Walsall. This inquiry embraced all the iron producing districts of the kingdom, for the years 1823 and 1830.

From this statement it is gathered, that the total yield of the Brecknockshire and Monmouthshire furnaces in the above named years, were 102,260 tons, and 156,277 tons; the number of furnaces in operation being respectively 35 and 68, in each of the same years.

Districts.	1823.		1830.	
	Furnaces.	Pig Iron.	Furnaces.	Pig Iron.
	No.	Tons.	No.	Tons.
Brecknockshire—				
Beaufort . . .	3	5,243	4	7,276
Clydach . . .	2	5,200	9	10,190
Hirwain . . .	2	4,160	4	9,360
Yniscedwyn. . .	1	1,498	2	2,111
Total . .	8	16,101	19	28,937
Monmouthshire—				
Abersychan . .	...	...	6	10,640
Blaenavon . . .	5	16,882	5	13,843
Blaina	...	...	3	4,905
Coalbrook Vale . .	1	2,704	2	2,780
EbbwVale & Sirhowey	6	20,425	6	26,020
Pentwyn . . .	...	...	3	5,391
Rhymney. . . .	...	...	1	220
Rhymney and Bute .	3	5,500	6	7,608
Tredegar . . .	5	16,385	5	18,514
Varteg. . . .	2	6,513	5	13,536
Nantyglo . . .	5	17,750	7	23,883
Total . .	27	86,159	49	127,340

Comparing the totals there is shown an increase of 33 furnaces and 54,017 tons of pig iron, equivalent to 50 per cent. The result arrived at by Mr. Finch shows that in 1823 the 266 furnaces in operation in Great Britain produced 455,166 tons, compared with 372 furnaces and 748,417 tons in the year 1830.

It thus appears that between the years 1823 and 1830 the increase in production was twofold, while the average yield of

each furnace increased from 1,736 tons in 1823 to 1,823 tons in the year 1830. About this period some interesting returns are at hand showing the make of pig iron in some of the more important works in these districts, which compare favorably with earlier returns of the same works in previous years. These are as follows :—

MONMOUTHSHIRE.

Year.	Blaenavon.	Tredegar.	Nantyglo.	Blaina.	Ebbw Vale.
	Tons.	Tons.	Tons.	Tons.	Tons.
1829	9,135	13,379	17,436	5,137	17,082
1830	9,401	12,335	17,536	4,292	18,258
1831	9,714	13,339	17,955	2,894	19,077
1832	9,066	13,372	21,333	8,058	18,347
1833	8,709	12,340	21,023	5,062	19,905
1834	8,391	12,920	22,663	6,074	20,240
1835	9,036	13,917	24,997	8,581	24,994
1836	7,596	12,133	25,407	9,020	22,957
1837	7,512	12,661	23,972	6,380	20,035
1838	8,085	15,538	25,241	7,458	23,320

These quantities refer solely to the works named. The Beaufort and Clydach works of Brecknockshire in each of the same years produced pig iron in the following quantities :—

BRECKNOCKSHIRE.

Year.	Beaufort.	Clydach.
	Tons.	Tons.
1829	7,102	7,431
1830	6,005	7,573
1831	5,153	7,031
1832	6,882	6,542
1833	7,522	7,384
1834	9,808	6,262
1835	12,979	7,562
1836	14,567	7,738
1837	11,162	7,087
1838	10,917	9,282
Total . .	92,097	73,892

In the period between 1830 and 1840 the iron industries of the county received a great impetus from the expansion of our railway system; all possible skill was brought to bear on the

improvement of the furnace, the quantity and quality of the iron. The old charcoal furnaces of small dimensions gave way to others of larger capacity, coke being employed; in height the charcoal furnaces varied from 12 to 18 feet, and even 28 feet where good water power existed, those of the coke furnaces being 40 and 50 feet, and even more in height, the width of the boshes varying from 10 to 15 feet. The production of the Monmouthshire and Brecknockshire furnaces till the year 1857 are included in the production of South Wales; after 1857, the number of furnaces and production of each district is separately distinguished. Before giving this summary the annexed statement, prepared from reliable sources, will show the total production of the several works in both Monmouthshire and Brecknockshire between the years 1829 and 1838 inclusive:—

MONMOUTHSHIRE.

WORKS.	PIG IRON. Tons.
Blaenavon	86,645
Blaina	62,956
Coalbroook Vale	29,889
Bute	72,040
Ebbw Vale	204,215
Nantyglo	217,563
Pontypool	48,835
Tredegar	131,934
Varteg	113,941

BRECKNOCKSHIRE.

Beaufort	92,088
Clydach	73,892

Mr. Francis Foster, writing about the year 1830, in his observations on the South Wales Coal Basin,* remarks "that the quantity of iron annually made in South Wales is calculated at 270,000 tons, three-quarters of which, it would appear, was converted into bars, and one-quarter into pigs and castings. The average quantity of coal required included that used by engines, workmen, &c., being about five and a half tons for each ton of pig iron made."

From the year 1857 the following table exhibits at a glance the number of furnaces built, in blast, and make of iron in each district:—

* Pamphlet, "South Wales Coal Basin," June, 1830.

Year.	Monmouthshire. Furnaces. Built.	Monmouthshire. Furnaces. In Blast.	Monmouthshire. Pig Iron.	Brecknockshire. Furnaces. Built.	Brecknockshire. Furnaces. In Blast.	Brecknockshire. Pig Iron Made.
	Nos.	Nos.	Tons.	Nos.	Nos.	Tons.
1857	68	54	399,649	16	14	70,779
1859	59	42	327,300	19	14	59,600
1861	74	54	338,439	17	10	43,300
1863	67	46	349,387	17	8	35,700
1865	68	45	367,656	17	10	49,750
1867	71	50	418,235	15	5	29,443
1869	59	44	472,450	17	6	39,201
1870	59	45	472,450	17	6	32,000
1871	62	47	470,982	17	4	30,086
1872	63	49	465,603	17	6	28,504
1873	62	42	360,583	...	...	...
1874	62	41	360,480	...	...	...
1875	62	37	262,253	...	...	...
1876	62	35	413,946	...	...	...
1877	61	30	368,480	...	...	...
1878	57	29	373,744	...	...	...
1879	57	27	337,684	...	...	...
1880	56	35	448,823	...	...	...

Brecknockshire has of late years disappeared from the published return as an iron producing district, and many of the furnaces have been dismantled.

Some interesting facts may be gathered from the above, showing the increased capacity and production of the furnaces during the past twenty years; thus in Monmouthshire in 1857 the average yield per furnace did not exceed 7,400 tons per annum, while in the year 1878 an average is shown of nearly 13,000 tons per furnace.

The success of the Blaenavon Works in the early part of the present century gave a great impetus to the iron trade in the Monmouthshire Hills, and a range of works sprung up to the westward, almost in a line near the heads of valleys that stretch towards Merthyr. Before giving the annexed statement showing the number of furnaces built, in blast, the respective firms, and the producing power of the works in the year 1880, the following dates, showing the establishment of some of the Monmouthshire works, will indicate the growth of the iron trade. The Beaufort, Ebbw Vale, Clydach, and Varteg works were in operation in 1803, Tredegar in 1805, Blaina and Coalbrook Vale before 1823, Abersychan in 1827, and Victoria in 1838.

MONMOUTHSHIRE.

No.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In Blast.
1	Abersychan	Ebbw Vale Steel, Iron, and Coal Co., Limited	6	4
2	Pontypool		4	2
3	Sirhowey		4	4
4	Ebbw Vale		4	4
5	Victoria		2	2
6	Blaenavon	Blaenavon Iron and Steel Co., Limited	9	5
7	Cwmbrân	Patent Iron and Bolt Co.	2	2
8	Nantyglo	Nantyglo and Blaina Iron Works Co., Limited	3	0
9	Blaina		3	0
10	Coalbrook Vale		1	0
11	Rhymney	Rhymney Iron Co., Limited.	9	6
12	Tredegar	Tredegar Iron Co., Limited	9	6
		Total of Monmouthshire	56	35

Glamorganshire.—In considering the production of pig iron manufacture in Glamorganshire, it will be convenient to consider the early history and progress of those works in which the reduction of the ores of iron is effected by coal of a bituminous character, and subsequently of those districts in which anthracite is exclusively employed.

As early as the 15th century evidence exists of the ores of iron being smelted in Glamorganshire, the furnaces being erected on the mountain tops, exposed to the wind, charcoal being alone used; at a later period the furnaces were erected on sites in the valleys where water power could be advantageously employed. The great consumption of charcoal necessary for iron smelting led to great scarcity of this necessary material; so much so that in the year 1740 the manufacture of iron was nearly extinct in South Wales, there being in that year but seven charcoal furnaces in operation, producing 2,000 tons of pig iron; of these two were in Glamorganshire and one in Caermarthenshire, making 500 tons, the others in Monmouthshire and Brecknockshire, four in number, making 1,500 tons. The total make of the 59 furnaces at that period amounting to 17,350 tons.

The Dowlais Iron Works, situated near Merthyr, were established by Messrs. Lewis and Guest about the year 1757; about 1776 Mr. A. Bacon erected a smelting furnace at Cyfarthfa, and

a forge for the manufacture of bar iron. In 1784 the Penydarren works were laid out by Messrs. J. Homfray and Co., and were a source of great profit. A few years later Mr. Homfray was the projector of a canal to Cardiff, which however was constructed under the direction of Mr. Richard Crawshay, who, on the demise of Mr. A. Bacon, toward the end of the century, became sole proprietor of the Cyfarthfa works, which he rapidly extended; other works succeeded, and in 1790 the Plymouth works were established.

The production of charcoal iron in 1788 from three furnaces in Glamorganshire and five in Caermarthenshire amounted to 2,200 tons, the make of coke pig iron in the same year in Glamorganshire being 6,600 tons, the yield of six furnaces.

Advancing to the year 1796, when Dr. Macnab's return appeared, the works showing the number of furnaces and make of pig iron in Glamorganshire were as follows :—

GLAMORGANSHIRE.

Works.	No. of Furnaces.	Excise Returns.	Supposed Quantities.	Exact Returns.
		Tons.	Tons.	Tons.
Caerphilly	1	600	600	695
Cyfarthfa	3	6,000	6,000	7,204
Dowlais	3	4,100	5,400	2,800
Ennisygedyr	1	1,352	1,352	800
Llanelly	1	1,664	1,664	1,560
Neath Abbey . . .	2	3,120	3,120	1,759
Penydarren	2	4,000	4,000	4,100
Plymouth	1	2,000	2,000	2,200
Melincourt	1	648	648	503
Total. . . .	15	23,484	24,784	21,621

The total yield of the 124 furnaces in blast in Great Britain the same year being 125,079 tons, giving an average make of 1,008 tons per furnace, compared with 796 tons per furnace in the year 1788.

In the interval before the next returns appear in 1806 the iron works of the Aberdare Company were established, adding to the works already existing. From the returns for that year the following abstract has been prepared, showing the number of blast furnaces built, in operation, and the make of pig iron in Glamorganshire, when of the 25 furnaces built, 21 were in blast, and produced 40,009 tons of pig iron, giving an average make of 1,905 tons per furnace :—

Works.	Furnaces.		Pig Iron Made.
	Built.	In Blast.	
	No.	No.	Tons.
Aberdare	2	2	3,586
Abernant	2	1	4,376
Caerphilly	1	1	1,000
Cyfarthfa	4	4	9,000
Dowlais	3	3	6,000
Ennisygedyr	1	1	1,000
Llanelly	2	2	2,267
Melincourt	1	1	1,000
Neath Abbey	2	0	...
Penydarren	3	3	6,780
Plymouth	3	3	5,000
Penraton	1	0	...
Total	25	21	40,009

It is a notable fact that at this period the only other districts in the kingdom exceeding the production of Glamorganshire were those of Staffordshire with 32 furnaces, yielding 50,002 tons, and Shropshire with 30 furnaces yielding 54,996 tons.

Mr. David Mushet, who made a special inquiry bearing on the production of pig iron in Great Britain, writes :—" In a survey I made of the iron works in 1820, my computation of the annual quantity of pig iron manufactured" was as follows, of which South Wales produced 150,000 tons :—

Districts.	Quantities.
	Tons.
South Wales, &c.	150,000
Staffordshire and Shropshire	180,000
Yorkshire and Derbyshire	50,000
Scotland and other places	20,000
Total	400,000

Mr. Frederick Finch, in his return prepared for the Government, of the make of pig iron for the years 1823 and 1830, gives the total production of the furnaces of South Wales in each of those years as follows :—

Year.	Furnaces.	Pig Iron.
	Nos.	Tons.
1823	72	182,325
1830	113	277,643

These figures show an increase in seven years of 41 furnaces and 95,318 tons, equivalent to 28 per cent. The average yield per furnace in 1823 was 2,532 tons, compared with 2,333 tons in 1830.

The Glamorganshire works produced pig iron in the following quantities in each of the same years according to Mr. Finch's statement:—

Name of Works.	1823.		1830.	
	No. of Furnaces.	Pig Iron.	No. of Furnaces.	Pig Iron.
		Tons.		Tons.
Aberdare	3	2,838	3	6,285
Abernant	3	2,838	3	6,285
Cyfarthfa	8	24,200	9	29,000
Dowlais	8	22,287	12	32,611
Gadly's	...	...	1	...
Maesteg	...	...	1	2,430
Pentyrch	1	1,235	1	2,412
Plymouth	3	6,387	5	18,582
Penydarren	5	15,547	5	17,015
Cwm Avon	1	1,560	1	1,950
Neath Abbey	...	...	2	2,374
Race	3	3,173	3	2,421
Total	35	80,065	46	121,365

Comparing the aggregate returns an increase is shown of 11 furnaces, and 41,300 tons, equivalent to 50 per cent.

About the year 1839 an interesting pamphlet appeared "On the State and Prospects of the Iron Trade in Scotland and South Wales."* The writer, in referring to the iron works of South Wales, gives some interesting facts and figures, showing the extent and capacity for production of pig iron of the works in Glamorganshire from which the following details are drawn.

The Aberdare Company's works in 1839 consisted of six furnaces in blast, two blown with hot air, and four with cold air, and producing from 350 to 400 tons of cast iron per week.

The Cyfarthfa Iron Works, belonging to Messrs. Crawshay and Sons, and the Hirwain Works of the same firm, situated about six miles from Merthyr, possess 14 blast furnaces, all blown with cold air, the 12 in operation producing weekly from 850 to 900 tons, the greater part of which is converted into malleable iron, of which they produce from 600 to 650 tons per week.

* By John Johnson, Esq., Iron Merchant, of Liverpool.

The Dowlais Works of Sir John Guest, Lewis and Co., had at this period 15 furnaces in full operation, and 4 others in course of erection; those in blast averaging 90 tons per week, giving a total weekly production of 1,350 tons.

The Plymouth Iron Works of Messrs. Richard and Anthony Hill consisted of 7 furnaces, all blown with cold air and making 700 tons of iron per week, 600 tons being converted into bar.

The Penydarren Iron Company have seven furnaces, six of which were in blast, making an average of from 400 to 500 tons of cast iron weekly, nearly the whole being converted into malleable iron.

The Pentyrch Iron Works of T. W. Booker, Esq., near Cardiff, have two blast furnaces blown with cold air, and yielding an average of 150 tons weekly of pig iron.

The returns from 1829 to 1839 of pig iron production, will show the magnitude of the iron works of Glamorganshire at this period; they are as follows:—

Year.	Aberdare.	Cyfarthfa.	Dowlais.	Plymouth.	Penydarren.
	Tons.	Tons.	Tons.	Tons.	Tons.
1829	8,644	24,768	23,352	13,534	10,085
1830	6,765	19,892	27,647	12,177	11,744
1831	6,903	15,465	22,075	10,198	11,819
1832	5,997	22,668	29,395	9,200	10,582
1833	6,964	37,380	35,072	12,093	12,150
1834	8,497	34,952	33,477	12,073	12,752
1835	9,261	35,090	39,145	12,631	12,834
1836	9,981	34,654	39,286	13,573	12,537
1837	9,830	33,580	38,914	15,353	12,834
1838	12,247	36,986	39,361	16,143	12,707
1839	11,307	37,009	40,495	15,762	15,540
Total	96,396	332,444	368,219	142,737	135,584

Much light is thrown upon the progress of the South Wales iron industries in the following returns:—

Year.	Furnaces.		Pig Iron Made.
	Built.	In Blast.	
	Nos.	Nos.	Tons.
1839	101	99	388,100
1840	163	132	505,000
1848	196	151	706,680
1852	162	135	635,000

Resuming with the year 1854, it appears that there were 154 furnaces built in South Wales, including Monmouthshire; of these 100 were in blast, making 750,000 tons of pig iron; the total production of the furnaces of Great Britain in the same year, when 555 were in blast, being 3,069,838 tons.

In the year 1857 and since, the production of the Glamorganshire furnaces is separately distinguished, and appears in the following table, with the average make per furnace:—

GLAMORGANSHIRE.

Year.	Furnaces. Built.	Furnaces. In Blast.	Pig Iron Made.	Average Make per Furnace.
	Nos.	Nos.	Tons.	Tons.
1857	87	76	436,859	5,748
1858	89	78	451,043	5,795
1859	89	73	539,470	7,390
1860	89	64	517,525	8,087
1861	82	59	453,821	7,692
1862	82	61	441,869	7,244
1863	82	60	439,722	7,349
1864	82	64	461,822	7,216
1865	81	64	408,416	6,384
1866	83	63	455,000	7,222
1867	76	49	403,050	6,226
1868	75	48	399,291	8,318
1869	79	53	348,475	6,575
1870	75	74	478,243	6,382
1871	72	53	510,087	9,064
1872	71	51	462,041	9,060
1873	78	51	424,384	8,321
1874	78	40	330,484	8,257
1875	78	35	249,667	7,133
1876	59	28	321,754	11,491
1877	76	26	342,478	13,172
1878	75	24	*367,392	15,308
1879	75	23	*332,174	14,442
1880	74	30	*440,915	14,697

The falling off in the average yield per furnace in 1880, being due to the additional furnaces being in operation for a part of the year only.

The works, owners, and number of furnaces built and in operation in the year 1880 were as follows:—

* This quantity includes the production of anthracite pig iron.

GLAMORGANSHIRE.

No.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In Blast.
			Nos.	Nos.
1	Brynamman	Amman Iron Co..	3	1½
2	Llwydcoed	The Aberdare and Plymouth Co., Limited	5	0
3	Abernant and Taffvale .			
4	Briton Ferry	Townshend, Wood & Co. . .	2	2
5	Cwm Avon, Port Talbot	Governor and Co. of Copper Miners in England . .	2	2
6	Cyfarthfa, Merthyr * .	Crawshay Brothers . .	10	6
7	Ynisfach			
8	Dowlais†	Dowlais Iron Co.	17	13
9	Llynvi, Maesteg . .	Llynvi, Tondu, and Ogmore Coal and Iron Co., Limited	6	1½
10	Gadlys, Aberdare . .	Waynes Merthyr Steam Coal and Iron Works, Limited .	4	0
11	Melin Griffith and Pentyrch.	Thos W. Booker & Co., Limited.	3	1
12	Plymouth, Merthyr. .	The Aberdare and Plymouth Co., Limited	10	0
13	Penydarren		7	0
14	Forest Iron and Steel, Pontypridd. . .	Forest Iron and Steel Co., Lim. .	3	2
15	Tondu, Bridgend . .	Llynvi, Tondu, and Ogmore Coal and Iron Co., Limited.	2	1
	Total of Glamorganshire .	. . . .	74	30

The following account of the Cyfarthfa Iron Works, from "Wilkin's History of Merthyr," written a quarter of a century since, will possess much interest, inasmuch as the works have been recently restarted, after an interval of five years' inactivity:—"Cyfarthfa Works now employ 4,000 to 5,000 men, who at a rough average, may be said to support 20,000 souls. There are eleven furnaces, seven mine pits, eight coal pits, and the yield of coal is 1,000 tons per foot thick per acre. The steam and water power used is equal to more than 4,000 horses, and the works in full force can produce 1,300 tons of pig iron, 1,000 to 1,100 tons of finished bars and railway iron weekly. Such is the result of a minute investigation of these magnificent works, so admired for their order and completeness. Seen by night by the traveller entering Merthyr from the Breconshire valley the picture is grand in the extreme. The border of the scene cast into deeper darkness by the brilliancy of the glare in turn adds to the fiery glow by its gloom. Forked tongues of flame leap up defiantly,

* Operations resumed in December, 1879, the works having been standing for several years. In the beginning of 1881 the manufacture of Bessemer pig iron was commenced.

† One furnace building.

and the very smoke is forced upwards, as it were, tinged with a ruddy glow. Here and there the molten iron sends forth an intense heat; myriads of fiery stars rush into the open air, and the clang and roar, the whirl of monster wheels, and shrill escape of steam, combine to form one of the grandest pictures of the terrible it is possible to conceive. Entering the works the force of the picture is enhanced. Standing by the rolls on each side are hardy, muscular men, wiry and active, whose duty seems to consist in pushing long red hot iron rails now through one roller and then through another, until they become of the required form and size. The dexterity with which the rails are handled is most startling. One moment's hesitation and nervousness would be followed by an accident, but there is no hesitation or nervousness there. Ribbon in a Coventry factory, calico on a Manchester loom, cloth in a Gloucestershire mill, wind not through with more care, nor are they handled with greater freedom and *sang froid*, though the rail is 600 pounds weight and of an intense white heat; watching this process for a minute, we see one of the men suddenly seize hold of the 600 pound rail with a pincers, pull it vigorously towards him and then, by the aid of a roller, run away with it as though it were a plaything, to a place where a saw, worked by machinery, cuts it to the required measurement, scattering with a hideous noise a thousand fiery sparks around. Then two men rush to each end and fashion them off smoothly, and the tortured iron is drawn out to cool. Every moment this process is carried on. There is no hesitation. Every man takes up his task like an automaton, little speaking is heard, but the toil and wear of the human machinery in this hard labour must be most excessive."

Anthracite Pig Iron.—The reduction of the ores of iron, by the agency of anthracite in the blast furnace, is of comparatively recent date, and the industry in Great Britain is confined exclusively to the western district of the South Wales Coal Field.

The successful application of anthracite as a reducing agent dates from the year 1836, and its use is intimately associated with the names of Mr. James Palmer Budd, of the Ystalyfera Iron Works, and of Mr. George Crane, of the Yniscedwyn Iron Works. The anthracite furnaces of South Wales are of small volume and height compared with the furnaces of other districts; their average height may be taken as from 36 to

40 feet; of late years, however, there is a tendency to increase not only the height but the capacity of those furnaces in which anthracite is employed. Anthracite in high furnaces is found attended with considerable difficulties, mainly due to its decrepitation tending to impede the smelting operation; this difficulty is overcome by increasing the density of the blast; the pressure employed varies from 4 to 6 lbs. to the square inch, while the heated air of the blast ranges from 320° to 500° C. Mr. Crane, in his early operations at Yniscedwyn in 1837, produced by the aid of anthracite in a furnace of the above named works 36 tons per week. In the following year it appears the industry was carried to the far west by a Mr. David Thomas from South Wales, who erected a furnace in the United States of America, at Maunch Chunk, in the Lehigh Valley, State of Pennsylvania.

Resuming with the anthracite districts of South Wales, the production in 1839, the first on record, it appears that of the 26 furnaces built, 23 were more or less actively employed, making of anthracite pig iron 65,780 tons, giving an average make per furnace of 2,860 tons, while in the same year the powers of production were being increased by the erection of eleven new furnaces. The make of pig iron in Great Britain in 1839 is shown in the annexed table:—

Districts.	Furnaces.		Pig Iron Made.
	Built.	In Blast.	
			Tons.
Derbyshire	16	14	34,372
Durham and Northumberland	5	5	13,000
Gloucestershire . . .	8	5	18,200
Lancashire (charcoal) . . .	2	2	800
Shropshire	34	29	80,940
Staffordshire, North . . .	10	3	18,200
Staffordshire, South . . .	226	120	346,213
Wales, North	20	13	33,800
Wales, South	101	99	388,100
Wales (Anthracite) . . .	26	23	65,780
Yorkshire	29	24	52,416
Scotland (coke iron) . . .	60	54	196,560
Scotland (charcoal) . . .	2	2	400
Total	539	393	1,248,781

Advancing to the year 1848, there appears to have been eight

works engaged in this manufacture, with 31 furnaces built, 14 of which were in blast, producing, as has been ascertained from reliable sources, between 60,000 and 65,000 tons of pig iron. The average make per furnace at this period may be taken as about 4,000 tons per annum. In the subjoined list appears a complete account of the works in South Wales in 1848, in which anthracite was employed as a reducing agent, together with the number of furnaces built, in blast, and the owners.

Name of Works.	Owners.	Furnaces.	
		Built.	In Blast.
Brecknockshire—			
Yniscedwyn . . .	Yniscedwyn Iron Co. .	7	3
Caermarthenshire—			
Gwendraeth . . .	T. Watney & Co. . .	3	2
Trimsaren . . .	E. H. Thomas . .	2	0
Bryn Amman . . .	L. Llewellyn & Co. . .	2	2
Glamorganshire—			
Banwen . . .	Joint Stock Co. . .	2	0
Onllwyn	John Williams . . .	2	2
Venalt	Aberdare Iron Co.. .	2	0
Ystalyfera . . .	Ystalyfera Iron Co. . .	11	5
Total . . .	. . . . . .	31	14

For a few years the production was well maintained, until 1857, since which it has gradually diminished, so much so that in the year 1880 the only furnaces producing anthracite pig iron were those of Ystalyfera, with eleven still standing as in 1848, of which four only were in blast, the estimated production not exceeding 14,000 or 15,000 tons of pig iron.

It has been observed that some varieties of anthracite decrepitate in a surprising degree when heated. Dr. Percy refers to specimens which he received from Neath, which, on the application of sudden heat, were reduced to absolute dust; and it is further remarked that the great difficulty experienced in the use of anthracite arises from the running together of the slag and the decrepitated particles of anthracite into an infusible mass, and gobbing up the furnace.

Following the production of anthracite pig iron in South Wales, the annexed table shows the number of furnaces built, and in blast, in each year since 1855, with the make of pig iron, and side by side the average yield per furnace.

ANTHRACITE PIG IRON.

Year.	FURNACES.		South Wales.	Average make per Furnace.
	Built.	In Blast.	Pig Iron.	
			Tons.	Tons.
1854	34	21	...	...
1855	34	19	52,755	2,776
1856	36	21	62,400	2,971
1857	36	20	63,440	3,172
1858	36	16	50,774	3,173
1859	36	18	58,920	2,162
1860	35	16	52,260	3,266
1861	31	14	50,740	3,643
1862	32	9	30,375	3,374
1863	31	9	22,944	2,549
1864	29	9	26,595	2,955
1865	29	9	29,213	3,246
1866	24	11	34,516	3,138
1867	25	11	35,506	3,228
1868	23	11	38,143	3,468
1869	23	9	27,909	3,101
1870	23	9	28,500	3,166
1871	19	8	34,761	4,345
1872	13	8	25,678	3,209
1873	13	8	32,822	4,103
1874	13	7	23,760	3,394
1875	13	7	29,889	4,270
1876	13	6	20,421	3,403
1877	13	4	*	...
1878	11	4	*	...
1879	11	4	*	...
1880	11	4	*	...

As previously remarked, the height and capacity of the anthracite furnaces have increased in late years; this is best shown in the average yield per furnace, taking the year 1855, when 19 furnaces produced 52,755 tons, the average yield was 2,776 tons, compared with 4,270 tons per furnace in 1875, when the make of 7 furnaces was 29,889 tons. The only works since 1876 engaged in South Wales in the production of anthracite pig iron, are those of the Ystalyfera Iron Company, the Yniscedwyn Company having discontinued the manufacture in the above named year.

Having generally traced the production of pig iron in the South Wales area, distinguishing that made in the bituminous and anthracite districts, as well as in each county, in the coalfields in which the iron industries are located, it only remains

* Estimated production between 14,000 and 15,000 tons.

to summarise the returns of each district and arrive at the total yield of the furnaces in South Wales. To this table is appended, the total number of furnaces, built and in blast, in each of the same years; the result being as follows:—

Year.	Bituminous District.			Anthracite District.	Total, South Wales.		
	Monmouthshire.	Brecknockshire.	Glamorganshire.	Glamorgan, Brecknock.	Furnaces.		Pig Iron.
					Built.	In Blast.	
	Tons.	Tons.	Tons.	Tons.	No.	No.	Tons.
1854	...	...	...	...	...	121	750,000
1855	*	*	787,315	52,755	...	148	840,070
1856	*	*	814,750	62,400	199	162	877,150
1857	399,649	70,779	436,859	63,440	207	164	970,727
1858	315,124	69,537	451,043	50,774	199	147	886,478
1859	327,300	59,600	539,470	58,920	213	147	985,290
1860	349,670	49,570	517,525	52,260	214	139	969,025
1861	338,439	43,300	453,821	50,740	200	137	886,300
1862	382,065	39,000	441,869	30,375	197	125	893,309
1863	349,387	35,700	439,722	22,944	197	123	847,753
1864	415,174	34,260	461,822	26,595	197	133	937,621
1865	357,656	49,750	408,416	29,213	195	128	845,035
1866	410,000	27,750	455,000	34,516	193	132	927,454
1867	418,235	29,443	403,050	35,506	185	115	886,234
1868	427,821	29,000	399,291	38,143	184	108	894,255
1869	392,387	32,201	348,475	27,909	178	112	800,972
1870	440,450	32,000	478,243	28,500	174	114	979,193
1871	470,982	30,086	510,087	34,761	167	112	1,045,916
1872	481,342	28,504	465,603	25,678	154	114	1,002,643
1873	360,583	nil	424,384	32,822	148	101	817,789
1874	360,480	nil	330,484	23,760	139	88	714,724
1875	362,253	nil	249,667	29,889	153	79	541,819
1876	413,946	nil	321,754	20,421	134	69	756,121
1877	368,480	nil	†342,478	...	150	60	710,958
1878	373,744	nil	†367,392	...	145	57	741,136
1879	337,684	nil	†332,174	...	145	54	669,858
1880	448,823	nil	†440,915	...	141	69	889,738

The returns for the years 1871 and 1872 show a great increase, due, as it may be remembered, to the prosperity reigning in those years; the causes of decline would in themselves present an interesting chapter; however, happily a new state of things now prevails, and a return of prosperity to the iron and other industries of the kingdom is, it is to be hoped, now set in.

Monmouthshire Mills and Forges, and Bessemer Steel Works.—These important works have existed from an early period in the

* Production included in the Glamorganshire returns in 1855 and 1856.

† Production of anthracite pig iron included in this quantity.

Monmouthshire extension of the South Wales coal-field. The earliest forges in operation employed charcoal and were established in the neighbourhood of Pontypool as far back as the 16th century: at a later period numerous works were established on the banks of the Ebbw river, Tredegar Park, and Machen. In the early part of the present century there existed eleven such works in Monmouthshire in which charcoal was exclusively employed, of which the following is a list:*—

FORGES.	PROPRIETORS.
Abercarne	Benjamin Hall & Co.
Bassoleg	Harfords & Co.
Caerleon	T. Buller & Co.
Gellywasted	Harfords & Co.
Machen	,,
Monmouth	Assignees of David Tanner.
Llanvillio	...
Newport	Sir Robert Salisbury & Co.
Pontypool	Capel Leigh & Co.
Tintern Abbey	Thomson & Co.
Trostre	Harvey & Co.

Of these works those at Abercarne and Tintern Abbey possessed furnaces, and wire-works, in addition to the forges. Not again until the year 1860, when the first published list appeared in the "Mineral Statistics of the United Kingdom," is any reliable information available; in that year, however, there were 16 works, of which 13 were in Monmouthshire and 3 in Brecknockshire, with a total of 345 puddling furnaces, and 40 rolling mills. Since 1860 the powers of production of many of these works have been greatly increased, while a few have been standing and others dismantled. The works and their resources stood as follows in each of the years named:—

Year.	No. of Works.	Puddling Furnaces.	Rolling Mills.
1865	16	570	60
1870	12	577	49
1875	13	597	54
1880	13	209	41

The annexed list gives the several works in Monmouthshire and Brecknockshire, with the numbers of puddling furnaces and rolling mills in operation in the year 1880:—

* See "General View of the Agriculture of the County of Monmouth," by Charles Hassall, 1812.

No.	Works.	Name of Firms.	Puddling Furnaces.	Rolling Mills.
	Monmouthshire—			
1	Abersychan	Ebbw Vale Iron Co.	...	...
2	Victoria	"	...	...
3	Ebbw Vale	"	64	17
4	Pontypool	"	20	4
5	Blaina	Nantyglo and Blaina Iron Works Co., Limited	...	...
6	Nantyglo	"	...	...
7	Blaenavon	Blaenavon Iron and Steel Co., Limited	...	...
8	Pontnewynydd	W. T. Henley	...	...
9	Rhymney	Rhymney Iron Co., Limited	18	7
10	Tredegar	Tredegar Iron and Coal Co., Limited	72	5
11	Oakfields	James C. Hill & Co., Lim.	12	4
12	Cwmbran	Patent Nut and Bolt Co.	23	4
	Total Monmouthshire		209	41
	Brecknockshire—			
1	Coedcae	The Welsh Iron Works Co.	...	...

The only works in Monmouthshire where steel is produced by the system associated with the name of Sir Henry Bessemer are those of the Ebbw Vale Company; these works were established in the year 1866, and at the present time possess six convertors, four of which have a capacity of eight tons and two a capacity of ten tons each; six cupolas being employed for supplying molten metal to the convertors. When actively employed these works can produce 1,000 tons of steel ingots per week, while one of the rail mills have been known in a single week to turn out 800 tons of finished rails. It was at these works that "speigelcisen" was first manufactured in this country, due to the energy and activity of Messrs. Richards and Parry, the engineer and chemist to these extensive works.

Coal used in Mills and Forges.—In these and the Tin Plate Works in Monmouthshire and Brecknock in the year 1873, the total consumption of coal may be set down as not less than 600,000 tons, but it will be remembered that during a period of three months the tin plate works were affected by a strike, which had the effect of diminishing the consumption of fuel by at least 100,000 tons; while in the year 1880 it probably did not exceed 460,000 tons. The average consumption of coal in the puddling

furnaces of this district may be set down as varying from 1,000 to 1,100 tons per annum.

Glamorganshire Mills and Forges. Bessemer Steel Works. —Here, as in Monmouthshire, mills and forges were in active operation cotemporary with the great iron works which have long flourished. In the year 1860 there were 16 of these malleable works in operation, with 628 puddling furnaces and 69 rolling mills; the resources since that period have been greatly augmented. The extent to which the works in Great Britain have extended from 1860 to 1875 is considerable, in the first named year, 208 works were in operation, increased to 314 in 1875, the number of puddling furnaces increasing from 3,462 to 7,575, and the rolling mills from 432 to 909 in each of the same years.

Of the iron works established since 1860 many have been closed for the past four or five years, and some have been entirely dismantled. The depreciation in the finished iron trade referable to Glamorganshire, may be gathered from the fact, that in 1870 there were 568 puddling furnaces in operation, compared with 340 in the year 1877, and 308 in the year 1880. The Dowlais Iron Works are the most extensive, with 150 puddling furnaces and 15 rolling mills; of these 65 furnaces and 15 mills were in operation in the year 1880. The Dowlais Company also possess important Bessemer steel works, the first introduced into this country. These were started in June, 1865; they at the present time consist of six convertors, two with a capacity of five tons, two of six tons, and two of seven and-a-half tons, or a total capacity of 37 tons, together with the usual blowing and hydraulic machinery. The Dowlais works in activity are capable of producing 1,500 tons of steel per week, consisting chiefly of railway bars and fastenings. In addition to which there are six furnaces constructed on the Siemens Martin system; the steel made by this process is employed for all purposes in which soft steel is ordinarily applied. In England it is used for casting screw propellers, and for various other high class steel castings.

At the celebrated French works at Creusot, steel containing 10 per cent. of carbon is manufactured by this process, and is used for piston rods, and other parts of steam engines, boiler plates, and more recently for shipbuilding.

Another important establishment to refer to, is the Landore Siemens Steel Company Works, situated at Landore, near Swansea:

the works consist of:—Two blast furnaces with Cowper's patent stoves, turning out when fully occupied 600 tons of pig iron per week; 24 Seimens' regenerative steel melting furnaces, making on an average 65 tons of steel per week; eight steam hammers of eight tons each, one four tons, and one two tons for making blooms for rails, tyres, &c., and for forgings; two rail mills complete with saws, straightening and other machines capable of making 1,300 tons of finished rails per week; beyond these are a tyre mill complete, bar mill for steel bars of all kinds, wire mill for rolling wire rods; 33 Siemens gas heating furnaces, for heating ingots and blooms for hammer and mills, with producers for making the necessary gas; 100 coke ovens for supplying coke to blast furnaces; brick-works for making the necessary bricks for the melting and other furnaces. The company also employ 64 steam engines of all sizes, besides five locomotives, foundries for casting both in steel and iron, and fitting shops. The coal properties of the company comprise all varieties of coal, coking coals, and anthracite, ensuring an unlimited supply of fuel; and in the steel works, when actively engaged, upwards of 2,000 men are employed.

Coal used in Mills and Forges (Glamorganshire).—In the years 1872 and 1873, when it was first attempted to gather information on this subject, it was ascertained that not less than from 750,000 to 800,000 tons were employed, including that used in tin plate manufacture, and even this last quantity is believed to fall short of that actually consumed; it is, however, stated on reliable authority that the average consumption of coal in the mills and forges of Glamorganshire is about from 1,200 tons to 1,300 tons per annum in the manufacture of 500 tons of bars or rails, it being also generally regarded that from five to five and-a-half tons of coal are required to bring each ton of bars or rails into their finished state.

The works of Glamorganshire, showing the number of puddling furnaces and rolling mills, were as follows in the years given:—

Year.	No. of Works.	Puddling Furnaces.	Rolling Mills.
1870	17	568	90
1875	18	526	85
1880	18	308	72

The list of the works in the last-named year, with the numbers

of puddling furnaces and rolling mills in operation, appear in the annexed table:—

GLAMORGANSHIRE.

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No of Puddling Furnaces.	No. of Rolling Mills.
1	Brynamman	Amman Iron Co.	Llanelly	10	2
2	Margam, Taibach	Robt. B. Byass & Co.	Aberavon	..	..
3	Clydach	Byrnmawr Coal and Iron Co., Limited	Abergavenny	..	..
4	Gadlys	Waynes Merthyr Steam Coal and Iron Works Co., Lim.	Aberdare	..	..
5	Llynvi	Llynvi, Tondu and Ogmore Coal and Iron Co.	Bridgend	33	4
6	Abernant, Taff Vale and Lewydcoed	Aberdare Iron Co.	Aberdare	..	..
7	Aberaman	Powell Duffryn Steam Coal Co.	"	..	..
8	Melin Griffith and Pentyrch	Thos. W. Booker & Co.	Cardiff	7*	14
9	Penydarran	The Aberdare and Plymouth Co., Limited	"	..	..
10	Briton Ferry	Townsend, Wood & Co.	Briton Ferry	43	4
11	Cyfarthfa	Robt. Crawshay	Merthyr Tydfil	61	5
12	Dowlais	Dowlais Iron Co.	"	65	15
13	Plymouth	The Aberdare and Plymouth Co., Limited	"	..	..
14	Cwm Avon, Taibach	Governor and Company of Copper Miners Successors	Port Talbot	..	..
15	Ystalyfera	Ystalyfera Iron Co.	Swansea	42	16
16	Pontardawe	W. Gilbertson & Co.	"	12	6
17	Tondu, Bridgend	Llynvi, Tondu and Ogmore Coal and Iron Co.	Tondu	23	3
18	College	Thomas Protheroe Gwillein and Thomas Williams	Llandaff	12	3
		Total of County		308	72

Coal used in Pig Iron Manufacture (Monmouthshire).—In all the early returns bearing on the use of coal, the returns of Monmouthshire are included in those of South Wales. In the year 1828, however, it was ascertained that five and-a-half tons of coal was used in each ton of pig iron manufactured. The results attained by the Royal Coal Commission show that in the year 1869 the average quantity employed did not exceed three tons, which included the necessary fuel for raising steam, engine fires blowing the blast, &c. About the year 1873 a select committee of the House of Commons was appointed to inquire into the high price of coal. It was at this juncture that the Mining Record Office, at the direction of the committee, made a special inquiry with a view of ascertaining the actual quantity of coal used in the iron manufactures of the kingdom, and the result was most satisfactory, inasmuch as it showed that considerable economy in the use of coal in the blast furnace had been secured.

In the Monmouthshire furnaces in 1873 it was subsequently

* Four double and three single furnaces.

ascertained that 48 cwts. of coal was the average quantity used in the manufacture of each ton of pig iron; in the Glamorganshire furnaces 49 cwts. was the average; while in the anthracite furnaces it amounted to 50 cwt.; and taking all the iron works in the kingdom it did not exceed 51 cwts.; while in Scotland, where raw coal was exclusively employed, the average reached 55 cwts. of coal to each ton of pig iron made.

As the consumption of fuel in the manufacture of pig iron will form the subject of inquiry in a future page it will be only necessary here, as in other districts, to record carefully the actual quantities employed, as they appear in the official returns, noting the average consumption of fuel to each ton of pig iron made, at the same time observing that in all cases where coke has been employed its equivalent in coal has been computed; thus, in the following years, the annexed figures show the quantities of pig iron made of coal used and the average quantity of coal to each ton of pig iron made, which includes all purposes in which heat is required, also the economy secured by the utilisation of the waste gases, which of late years have been considerable:—

MONMOUTHSHIRE (BITUMINOUS).

Year.	Furnaces.		Pig Iron Made.	Coal Used.	Coal, per ton.
	Built.	In Blast.	Tons.	Tons.	Cwts.
1872	63	49	465,603	1,117,626	48
1873	62	42	360,583	867,640	48
1874	62	41	360,480	901,200	50
1875	62	37	262,253	577,272	44
1876	62	35	413,946	879,732	43
1877	62	30	368,480	832,723	45
1878	57	29	373,744	879,721	47
1879	57	27	337,684	769,894	45½
1880	56	35	448,823	1,045,449	46

Coal used in Manufacture (Glamorganshire).—In the furnaces of Glamorganshire, in the bituminous coal districts, it has been ascertained that about the year 1830 four tons of coal were consumed in the manufacture of each ton of iron. In South Staffordshire in the same year the average varied from six to six-and-a-half tons, while in Scotland where raw coal was chiefly employed, the quantity varied from seven-and-a-half to eight tons. A very different state of things now exists, increased economy

being secured, by the many improvements introduced into the smelting operations of the blast furnace since that date, all of which will be generally referred to.

With the year 1872 fairly reliable information is at hand, showing the consumption of fuel, and in the following summary will be seen the proportion of fuel consumed to each ton of pig iron made in the furnaces of Glamorganshire in which bituminous coal was exclusively used :—

GLAMORGANSHIRE (BITUMINOUS).

Year.	Furnaces.		Pig Iron Made.	Coal Used.	Coal per ton.
	Built.	In Blast.			
			Tons.	Tons.	Cwts.
1872	71	51	462,041	1,172,453	50
1873	78	51	424,384	1,047,245	49½
1874	78	40	330,484	668,769	40
1875	78	35	249,667	531,036	42½
1876	59	28	321,754	660,558	41
1877	76	26	342,478	739,274	43
1878	75	24	367,392	755,126	41
1879	75	23	332,174	684,249	41¼
1880	74	30	440,915	922,155	41¾

Some little variation appears in the last column in the average quantities of coal used to each ton of iron made; however the figures as a whole show economy.

In Brecknockshire in the year 1872, the last year in which it appears as an iron producing district, the 28,504 tons of pig iron made in the Beaufort furnaces, with the expenditure of 88,519 tons of coal, gives an average of 62 cwts. of coal to each ton of pig iron made.

Coal used in Manufacture (Anthracite Furnaces).—Attention has been already called to the use of anthracite as a reducing agent in the smelting of the ores of iron in the blast furnace, and accomplished at the Yniscedwyn Iron Works by Mr. George Crane, in the year 1836, and by Mr. J. Palmer Budd, of the Ystalyfera Iron Works in the same year. Anthracite possesses many characteristics, and these are clearly described by Dr. Percy, in his recent Metallurgical volume on Fuel:—"It is very compact, deep black, both when massive and in powder; bright, occasionally somewhat bronzelike, or sub-metallic in lustre, brittle, uneven, or conchoidal in fracture; it does not soil the fingers; it burns with a feebly luminous flame, and is much less

easily combustible than other kinds of coal, and when heated does not in the least sinter; some varieties decrepitate considerably, even when gradually heated." When converted into coke, the small is selected and in admixture with caking coals, pitch or coal tar, in varying proportions, is heated at a high temperature.

Anthracite, owing to its density and purity, yields pig iron of good quality, and in order to overcome its decrepitation in the furnace, and secure satisfactory results, hot blast of a high pressure must be employed. The average quantity of anthracite used in the manufacture of pig iron is variously stated; some twenty-five years since it exceeded 50 cwts.; but in recent years, as far as can be ascertained, it has varied from 48 cwts. to 50 cwts. In one instance at the Yniscedwyn works, it appears on the authority of Mr. S. Kenyon Rogers, that his uncle, Mr. Blackwell, at the above-named works, made pig iron with a consumption of 18 cwts. 2 qrs. and 9 lbs. of anthracite per ton. In the anthracite furnaces of South Wales a pressure of blast of from 4 to 6 lbs. is used; while in the anthracite furnaces of Pennsylvania, in the United States, of larger capacity, the pressure varies from 6½ to 7½ lbs. pressure on the square inch.

In all the computations where fuel is used in the manufacture of pig iron, it will be understood that the quantity for heating the blast, &c., is included; in the case, however, above referred to, of Mr. Blackwell's experiment, in addition to the 18 cwts. 2 qrs. and 9 lbs. employed in the blast furnace, a further amount of 8 cwts. 3 qrs. and 11 lbs., was used for the heating of the boilers in raising steam, making the total quantity of anthracite used 27 cwts. 1 qr. 20 lbs. to each ton of pig iron made. The pig iron thus manufactured, it should be stated, was particularly suitable for conversion into steel, on account of the freedom of the anthracite from sulphur. An average sample of anthracite employed in smelting, contains of sulphur 0·70 per cent., of ash 9·14 per cent.; the ash consisting of silicate of alumina, a small quantity of lime, and a trace of peroxide of iron. Sulphur is always present in coal, in combination with iron pyrites, or bisulphide of iron, from which no coal is entirely free, and is either disseminated through the mass, so as to be invisible, or occurring in laminæ of a brass yellow colour, and sometimes in layers or nodules of considerable size.

Previous to the introduction of apparatus at the mouth of the blast furnace, for the collection and utilisation of the waste gases, it has been estimated that fully two-thirds of the total quantity of heat produced in the blast furnace escaped and was lost. The problem was solved at the Ystalyfera Iron Works by Mr. Budd, and considerable economy has been the result. It would appear that the first idea for utilising the heat of the gases and vapours escaping from the funnel head, was to conduct this hot air through the hot air stove, and use it instead of coal for heating the air which was to be blown into the furnace. In carrying out this arrangement Mr. Budd states that he constructed his stoves for heating the blast in such a manner that a portion of the hot gaseous escape from the top of the furnace was drawn through them and thus economised; previous to the introduction of this arrangment the three stoves required to heat the blast at the Ystalyfera furnaces consumed 35 tons of coal a-week, and required the attendance of two men.

These gases, it should be stated, entered the stove at a temperature of 1800° Fahr., and left it at about 800° Fahr., while the temperature required for the blast did not exceed 600°; thus it will be seen that the heated gases above, without any access of air, supplied more than the heat required, the gases, it must be remembered, escaping at such a temperature that if air was admitted to them they would at once burst into combustion, and thus form another source of heat which has been utilised in many of the iron works of the kingdom in raising steam, and experience shows that the higher the temperature of the blast employed in the furnace the less fuel will be required, while in every case the waste gases from the blast furnaces would be found sufficient to heat the blast, and produce all the steam required for the blast furnaces, and that in addition they might be used to calcine the mine.*

Taking the actual returns of pig iron made in the anthracite furnaces in the year 1872, when eight furnaces produced 25,678 tons, consuming 72,392 tons of anthracite, an average consumption of 56 cwts. appears to each ton of iron made: this appears excessive; however it doubtless includes all fuel used.

In the annexed table is given the number of furnaces built and

* A term commonly used in South Wales for ore.

in blast, the pig iron made, coal used, and the average quantity per ton, in the anthracite furnaces:—

GLAMORGANSHIRE (ANTHRACITE).

Year.	Furnaces.		Pig Iron Made.	Coal Used.	Average of Coal per Ton.
	Built.	In Blast.			
	No.	No.	Tons.	Tons.	Cwts.
1872	13	8	25,678	72,392	56
1873	13	8	32,822	81,837	50
1874	13	7	23,760	57,240	49
1875	13	7	29,889	61,169	41
1876	13	6	20,421	52,997	51
1877	13	4	*	...	...
1878	13	4	*	...	...
1879	13	4	*	...	...
1880	11	4	*	...	...

The average consumption of coal used as stated above in the year 1875 as 41 cwts. is clearly far below the quantity employed, however, it appears, that if the average be taken at 50 cwt. it will be very near the exact quantity.

Coal used in Pig Iron Manufacture in South Wales.—The production of pig iron and of coal used, in each division of the South Wales mineral field, has been considered; namely, the bituminous districts of Monmouthshire and Brecknockshire, Glamorganshire, and the district in which anthracite is exclusively employed. The next step will be to follow the production of pig iron and of coal used in South Wales as one district, and trace the progress of the economy in the use of fuel. It has been previously stated that about the year 1830 four tons of coal was the average quantity employed in producing each ton of pig iron in South Wales. Since the year 1872, when special attention was devoted to this important subject, by the Mining Record Office, much additional light has been thrown upon it.

In the annexed summary is shown the number of furnaces built and in blast, and the proportion of coal to iron used in the South Wales furnaces. In the year 1878 the total number of blast furnaces in Great Britain numbered 683 in blast, the number built being 892, the make of pig iron was 6,566,457 tons, the coal used 16,718,532 tons; taking these figures the average con-

* The estimated production in each of those years did not exceed from 14,000 to 15,000 tons.

sumption of coal appears to have been 51 cwts. to each ton of pig iron made, comparing favourably with the year 1869, when the average amounted to 60 cwts. :—

SOUTH WALES (INCLUDING MONMOUTHSHIRE).

Year.	Furnaces.		Pig Iron Made.	Coal Used.	Average Coal per Ton.
	Built.	In Blast.			
	No.	No.	Tons.	Tons.	Cwts.
1872	154	114	1,002,643	2,450,990	49
1873	148	101	817,789	1,996,722	48½
1874	139	88	714,724	1,627,209	45½
1875	153	79	541,819	1,169,477	43½
1876	134	69	756,121	1,593,487	42
1877	150	60	710,958	1,571,997	44
1878	145	57	741,136	1,634,847	44
1879	145	54	669,858	1,454,143	43½
1880	140	68	889,738	1,967,604	43½

The utilisation of the waste gases, introduced by Mr. Budd, of the Ystalyfera Iron Works, Swansea, some years after the application of the hot blast by Mr. Neilson, has been a fruitful source of economy, from four tons of coal to each ton of iron made in 1830, to 51 cwts. in the year 1872. Various arrangements have been successfully applied towards this end, all of which will be found fully described in the works of the great authorities on metallurgy, the matter being generally referred to here as a cause for the diminution in the consumption of fuel in iron making. On the continent of Europe, where fuel was more expensive, the utilisation of the waste gases was introduced at an earlier period than in this country; however, at present the system is, with few exceptions, universally adopted in all our iron-producing districts.

Iron Ore used in the Manufacture of Pig Iron.—The total quantity of ironstone of all varieties used in the make of pig iron in the blast furnaces of Monmouthshire in the year 1873 was 792,094 tons. The ironstone or "mine" of the district when smelted alone yields from 32 to 33 per cent. of metallic iron, and in this proportion would require for each ton of pig iron made, from 60 to 62 cwts. The admixture of other ores obtained from Lancashire and Cumberland, as well as ores imported from Spain, all rich in metallic iron and extensively employed in the district, reduce the bulk of ore required to an average of about 44 cwts. of raw stone to each ton of pig iron made. The iron

ore smelted in this district in 1873 may be approximately stated as follows:—

DISTRICTS.	TONS.
Native mine	502,734
Foreign ores	140,000
Somersetshire	29,360
Forest of Dean, Northamptonshire, Cornwall, Lancashire, Ireland	120,000
Total	792,094

The metallic iron contained in the foreign ores vary from 50 to 60 per cent., the hæmatite ore of the Forest of Dean from 62 to 63 per cent., the Northamptonshire ore 40 per cent., the Cornish ores from 50 to 60 per cent., the rich red ores of Lancashire and Cumberland from 60 to 64 per cent., and the aluminous ores from the North of Ireland, from 35 to 40 per cent. In subsequent years since 1872 ores of all kinds in the following quantities have been smelted in the furnaces of Monmouthshire:—

Year.	Pig Iron.	Iron Ore.
	Tons.	Tons.
1873	360,583	792,094
1874	360,480	760,600
1875	262,253	536,367
1876	413,946	828,865
1877	368,480	719,869
1878	373,744	749,588
1879	337,684	644,248
1880	448,823	811,743

The argillaceous ores of the coal measures, or native mine, when calcined, lose from 27 to 30 per cent., an amount that is made up of the water and carbonic acid that is driven off, diminished by the oxygen taken up in the conversion of the protoxides of iron and manganese into magnetic oxides. As far as can be ascertained in the years 1878 and 1879 the iron ore reduced in the Monmouthshire furnaces, was derived from the following districts. The total production of iron ore in 1880, in South Wales, amounted to 343,927, of which 278,361 tons were argillaceous, and 65,566 tons hematitic:—

Districts.	1878.	1879.
	Tons.	Tons.
Native mine	276,974	253,789
Foreign ores	326,614	308,299
Somersetshire	40,000	21,736
Forest of Dean, Northamptonshire, Cornwall, Ireland, &c.	106,000	20,000
Lancashire and Cumberland	...	40,424
Total	749,588	644,248

In the Glamorganshire furnaces in the year 1873 the quantity of iron ore smelted amounted to 854,171 tons, producing 424,384 tons of pig iron; and as far as can be ascertained this quantity was obtained from the following sources:—

	TONS.
Argillaceous ores (Native mine)	248,777
Foreign ores (ascertained)	155,082
Various (British and foreign)	450,312
Total	854,171

In the metallurgical works of this district in late years the main bulk of the ores smelted consist of foreign ores; in one establishment from 30 to 34 cwts. of these rich ores yield one ton of pig iron, in other works the quantity varies according to the admixture of ores employed, ranging from 38 to 40, 44 and 47 cwts. to each ton of pig iron made, a careful examination of the quantity showing that the average consumption of ore to one ton of crude metal may be taken as 40 cwts. 1 qr. As far as can be ascertained the following quantities represent the total tons of all kinds of ore used in each of the years since 1873 in the Glamorganshire furnaces, the pig iron made being also given:—

Year.	Pig Iron.	Iron Ore.
	Tons.	Tons.
1873	424,384	854,171
1874	330,484	638,359
1875	249,667	479,612
1876	321,754	640,768
1877	342,478	667,619
1878	367,392	699,769
1879	332,174	643,398
1880	440,915	787,279

In the Anthracite district in the year 1873 the total quantity of ironstone of all kinds employed in the manufacture of 32,822 tons of pig iron, was 77,000 tons; the great bulk of this ore was obtained from foreign countries, the ironstone of the district did not exceed 20,000 tons of the quantity; the Spanish ores as previously stated yielding from 50 to 60 per cent. of metallic iron.

Taking all the facts obtainable the average quantity of ore of all kinds used in this district in obtaining one ton of pig iron may be set down as 48 or 49 cwts., and it may be observed that under the most favourable circumstances it rarely happens that the whole of the metal contained in the ore is obtained, a portion remaining in the cinder. In each of the years since 1873 the annexed quantities show generally the proportion of iron ore to the pig iron obtained in the anthracite furnaces :—

Year.	Pig Iron.	Iron Ore.
	Tons.	Tons.
1873	32,822	77,000
1874	23,760	53,487
1875	29,889	61,780
1876	20,421	56,263

The annual production of anthracite pig iron since 1876 has not exceeded 15,000 tons, the iron ore employed amounting to about 40,000 tons.

Having generally considered the quantites of iron ore and ironstone of all kinds employed in the blast furnaces of South Wales, it only remains to summarise results and tabulate the quantities in the aggregate; thus in each of the years since 1872 the annexed table shows the make of pig iron in South Wales and the total quantities of iron ore employed :—

South Wales (including Monmouthshire).

Year.	Pig Iron.	Iron Ore.
	Tons.	Tons.
1873	817,789	1,723,265
1874	714,724	1,452,446
1875	541,819	1,077,759
1876	756,121	1,525,896
1877	725,958	1,427,488
1878	756,136	1,529,357
1879	669,858	1,287,646
1880	889,738	1,599,022

An examination of the above figures shows that since the first-named year the foreign ores have been more extensively employed in the furnaces of South Wales; this is apparent in the increased quantities imported in each of the years 1878 and 1879. It is also a matter of fact that during the same years the argillaceous ores of the district have been somewhat less employed. This will be better understood when the figures are reduced to an average, from which it appears that 42 cwts. were required to make a ton of pig iron in the year 1873; 40½ cwts. in 1878; 38½ cwts. in 1879, and but 36½ cwts. in the year 1880.

CHAPTER XVI.

GLOUCESTERSHIRE IRON INDUSTRIES.

Iron Ore of the Carboniferous Limestone—Description of Deposits—Mines in Operation in 1880—Analyses and Production of Brown Iron Ore—Output of the more important Mines—Distribution of the Forest of Dean Ore—Pig Iron Manufacture—Early History—Production and Yield of Furnaces—Malleable Iron Works, early history—Quantities of Coal and Iron Ore used in Pig Iron Manufacture.

Iron Ore Deposits.—The valuable ores of iron occurring in the carboniferous or mountain limestone, in the Forest of Dean, appear to have been worked about the year 1650, and again, though on a limited scale, in the beginning of the present century; this latter fact we glean from the "Survey of Gloucestershire," by Mr. Thomas Rudge, who states that in the year 1806 the greater part of the ore employed in the blast furnaces, was obtained from Lancashire, and that the ironmasters found it more profitable to import this ore, notwithstanding the high rate of carriage then charged, rather than employ the ores of the district. As the rich character of the Forest hematite became better known the deposits were more fully developed. The year of greatest production was 1871, when the output of the iron mines in the Forest reached 170,611 tons, of the value of £127,957.

In the millstone grit formation the ore is worked but very locally, the principal masses being found in the mountain limestone, where it exists in irregular chambers or "churns," some of which are of considerable extent, yielding many thousands of tons, and having the additional advantage of being worked economically, from the circumstance that no timbering or other supports for the roof is required. The ore is in good request in the ironworks of South Wales and other districts; the quantities, however, sent out of the Forest of Dean have decreased considerably of late years.

Most of the coal-fields of Great Britain possess in a greater or less degree productive measures of ironstone; in the years 1879 and 1880 upwards of one-third of the ironstone raised in the United Kingdom was derived from the argillaceous ores of the coal measures. South Wales, Staffordshire, Derbyshire, Yorkshire and Shropshire, North Wales, and Scotland, are amongst our coal-fields most abundantly supplied with these ores, while, on the other hand, in the coal-fields of Durham and Northumberland, Lancashire and the Forest of Dean, these argillaceous ores of iron are of rare occurrence; their absence, however, in Gloucestershire is amply compensated for by the almost unlimited deposits of brown hematite, occurring in the carboniferous limestone—a rock of a tough crystalline character, bluish-grey in colour, and emitting when fractured a sulphurous odour, due to the presence and decomposition of iron pyrites. This limestone is of considerable value commercially, being used as a flux, and employed as a road metal.

The principal deposits of brown hematite in the Forest of Dean occur in the carboniferous or mountain limestone in extensive hollows, or chambers, caverns, or churns. The mines are situated for the most part on the outcrop or basset of the mineral basin, and many of them are worked to a considerable depth. At the Buckshraft Mine, one of the earliest wrought mines in the Forest on the eastern side, the hematite is worked at a depth of 250 yards below the level of the outcrop. Various opinions have been recorded as to the extension of these valuable deposits of brown hematite in depth. The Forest of Dean was examined and reported upon some years since, in 1835, by Thomas Sopwith, Esq., F.R.S., one of the Commissioners on behalf of Her Majesty's Commissioners of Woods and Forests; the results of this survey were at a later period delineated in a most interesting and instructive model of the Forest of Dean, now deposited in the Museum of Practical Geology, in Jermyn-street. Again, in the year 1855 the officers of the Geological Survey surveyed the Forest, acting under the direction of the late Sir Henry de la Beche.

Generally it may be regarded that the greatest depth of the coal measures in the Forest mineral basin does not exceed 500 yards from the high water level of the River Severn, while the iron ore deposits, if they occur, are not more than 100 yards

below the coal measures; doubtless, with the winning of the brown hematite at this great depth, considerable difficulties will be experienced in the matter of drainage, from the accumulation of water which would be met with in sinking to the deep of the mineral basin through the coal measures. It is stated that in the Shakemantle Pit, in the Buckshraft Mine, at the depth of 120 yards, the quantity of water encountered does not exceed 2,000 gallons per minute in the worst season of the year. This pit is considerably below the level of the River Severn, draining, probably, the whole of the waters from the outcrop, a distance of nearly three miles north and south. The cylinder of the pumping-engine employed at the above-named pit by Messrs. Crawshay has a diameter of 60 inches, and successfully keeps the mine free of water.

The dip of the strata of the mineral basin near the outcrop on the eastern side of the Forest is about 45 degrees, decreasing gradually towards the centre of the basin, till it reaches the Light Moor Colliery, where it diminishes to 4 degrees, rising again towards the westward, where the strata have the same inclination as on the eastern outcrop.

The question of the occurrence in depth of the brown iron ore is an all-important one; it does not appear improbable, that it will be found deep, and so far as the subterranean operations of the district have been carried, no diminution is apparent either in the quantity or character of the ore wrought. The question has received much attention, and will probably be determined at no distant period, inasmuch as on the eastern side of the Forest, immediately adjoining the Cinderford property of Messrs. Crawshay & Co., are a series of "gales," or royalties, of iron mines known as the Polar Star, Duke of Gloucester, Emperor Napoleon, Berkeley Castle, and Elephant, comprising an area of upwards of 2,000 acres, or 3 square miles, and situated some 6 miles north of Lydney, 4½ miles east of Coleford, and 2½ miles west of Newnham, and favourably situated in regard to railway communication, being intersected by two lines.

Within the above-named area it has been recommended that shafts be sunk in suitable positions by the aid of Messrs. Kind's and Chaudron's pit sinking machinery, iron tubbing being employed to deal more effectually with the influx of water expected to be encountered in these operations. An important

and extensive work of this kind must of necessity be attended with considerable outlay of capital, and calls for the employment not only of large resources, but of great engineering experience and sound judgment in its accomplishment. It is well deserving the attention of the ironmasters connected with these industries, in view of securing future supplies to supplement the diminishing resources of the blackband ironstone, to aid in the solution of the problem, namely, the discovery of the rich brown hematite deposits, supposed to extend to the centre of the mineral basin in the Forest of Dean.

Before passing on to the analyses of the ores, a list of the iron mines in the Forest of Dean, their situation, and the firms working the same, may be found convenient for reference; they were as follows in the year 1880:—

No.	Name of Mine.	Situation.	Name of Proprietor or Company.
1	Buckshraft	Cinderford	Hy. Crawshay and Son.
2	Coleford	Coleford	Coleford Iron Co.
3	Easter	"	Easter Hæmatite Iron Ore Co., Limited.
4	Forget-me-not	Bream	J. W. Blanch and Wood.
5	Oakwood Mill Upper	Noxon	Forest Hæmatite Iron Ore Co., Limited.
6	New China Level		
7	New China Engine		
8	Oakwood Deep Level	Bream	William James.
9	New Dun Pit	Coleford	Coleford Iron Co.
10	Lydbrook	Lydney	Thomas Smith.
11	Noxen Park	Bream	Great Western Iron Co., Lim.
12	Old Bow and Tufthorn	Clearwell Meend	G. Atkinson.
13	Old Ham Pit	" "	William Henry Fryer.
14	Old Sling Pit	" "	" "
15	Old Park	Bream	Blanch and Wood.
16	Park Hill	Lydney	H. Crawshay and Son.
17	Perseverance	Newnham	" "
18	Shraves	Bream	Thomas Hewlett.
19	St. Annals Oak Pit, Shraves	"	J. Hewlett.
20	Westbury Brook (Edge Hill.)	Mitcheldean	Dowlais Iron Co.
21	Dean's Meend	"	" "
22	Slope Pit	Coleford	William James.
23	Staunton	Staunton	Highmeadow Iron Mining Co., Limited.
24	Scar Pit	Bream	William James.
25	Lufton Frog Pit	"	" "
26	Kingsmoor	Noxon	Great Western Iron Co., Lim.
27	Yew Tree Shraves	Bream	John Shingles.
28	Tufton	Coleford	Great Western Iron Co., Lim.
29	Lambs Quay	Clearwell Meend	W. H. Fryer.
30	Lower Oakwood Mill	Bream	William James.
31	Lydney Park	"	Lydney and Wigpool Iron Ore Co.
32	Saint Annals	Cinderford	H. Crawshay and Sons.
33	Wigpool Belt and Injunction Belt	Mitcheldean Meend	Lydney and Wigpool Iron Ore Co., Limited.

Analyses of the Forest of Dean Brown Iron Ore or Limonite.— The hematite of this district, as far as it has been worked, has been thoroughly examined, and numerous analyses are at hand to show the composition of the several varieties. The varieties may be classified as follows: first, a very compact close-grained black ore, of high per centage, locally termed "Brush Ore," sometimes met with in large lumps weighing from two to three tons, but more generally in small masses mixed with the other ores;—secondly, a cellular or spongy variety, often tough, also black and very rich, and occasionally occurring in large quantities; and thirdly, a broken, earthy-looking ore, assuming, on exposure in heaps to the air, a deep red colour, not very rich in itself but extensively used in admixture with the two previous varieties, and it appears to form nearly two-thirds of the bulk of the ore raised in the district.

In the smelting of the ores of this locality considerable facilities are afforded by the abundance of good and cheap fuel from the Forest collieries, and when fluxing material is required, from the limestone of the neighbouring hills. On the principal floor of the Museum of Practical Geology will be found in the wall cases numbered 48 and 49 a large collection of the ores of iron wrought in Dean Forest, described as Brown Iron Ore, one variety distinguished as very compact "Sandstone Ore"; a second from the Mountain Limestone, locally called "Grey Ore"; a third, provincially called "Smith Ore"; and a fourth of a cellular or tubiporous variety, raised at the Easter Mine, near Coleford.*

An examination of two varieties of ore by Mr. Charles Greenham, of the Park End Ironworks, made some years since, the samples submitted to analyses being described as follows: "first, the "Brush Ore," the sample was composed mainly of fragments of the purple-brown hydrated peroxide of iron, having the peculiar stalactitic structure which characterises this ore. A smaller quantity of the brown pulverulent variety was intermixed with the former, and therefore included in the "sample analyses." Another variety, the "Grey Vein," is thus referred to: this ore appears to have been derived from the brush ore by the partial filling up of the cavities, with a crystallised carbonate of lime and magnesia." The following shows the constituents of each of the varieties:—

* "Catalogue, Mineral Collection, Museum of Practical Geology," 1864, p. 5.

Constituents.	Brush Ore.	Grey Vein.
Peroxide of iron	90·70	41·86
Protoxide of iron	traces.	traces.
Oxide of manganese		
Carbonate of lime		30·40
Phosphoric acid	0·07	0·13
Water	8·87	4·65
Sand and clay	0·60	1·32
Carbonate of magnesia	...	21·50
Total	100·24	99·86

Of these ores the "Brush Ore" yielded of metallic iron 63·50 per cent., and the "Grey Vein" 29·30 per cent. It is further observable that neither of the above samples contains any appreciable amount of sulphur.

The Forest of Dean ores have also been examined in Dr. Percy's laboratory of the Royal School of Mines by Mr. A. Dick, whose results are shown in the annexed statement; the ores examined being those known as the "Brush Ore" and the "Smith Ore," the latter being a more earthy variety derived from the carboniferous rocks:—

Constituents.	Brush Ore.	Smith Ore.
Peroxide of iron	90·05	89·76
Protoxide of manganese	0·08	0·04
Lime	0·06	0·49
Alumina	...	0·63
Magnesia	0·20	0·40
Phosphoric acid	0·09	0·13
Water	9·22	7·05
Insoluble residue	1·07	2·57
Total	100·77	101·07

The "Brush Ore," in the foregoing analysis, was found to contain 63·04 per cent. of metallic iron, while that of the Smith Ore was equivalent to 62·86 per cent. These hematites compare favourably with those of Llantrissant, siliceous in character, yielding an average of 41·34 per cent. of metallic iron.

In the north-western district of the Forest there are two descriptions of ore worked, known locally as "Brandy Brush" and "Grey Ore," the former distinguished for containing a high per centage of silica, and the latter of carbonate of lime and silica.

The "Brandy Brush" ore also appears in a few other localities, while the Grey Ore chiefly appears on the western side of the mineral basin near Coleford. The following gives the composition of each variety of these ores; the examination was made in the laboratory of the Royal School of Mines:—

Constituents.	Brandy Brush.	Grey Ore.
Sesquioxide of iron	32·76	48·98
Protoxide of iron	...	0·24
Protoxide of manganese . .	trace.	0·16
Alumina	0·05	0·12
Lime	0·25	14·07
Magnesia	0·25	10·21
Potash	...	...
Silica	0·07	...
Carbonic acid	...	20·75
Phosphoric acid	0·09	0·06
Sulphuric acid.	trace.	trace.
Water hygroscopic	3·55	5·18
Organic matter	...	...
Ignited insoluble matter . .	63·38	0·86
Total . .	100·40	100·63
IGNITED INSOLUBLE RESIDUE.		
Silica	63·45	0·79
Alumina	traces.	0·05
Sesquioxide of iron . . .	traces.	0·01
Total . .	63·45	0·85

The metallic iron contained in these ores are equivalent respectively to 22·93 and 34·46 per cent.

The ores raised on the eastern side of the Forest, at the well-known mines of Buckshraft, Findall, and Westbury Brook, appear to be more easily dealt with in the blast furnace than the ores obtained on the north-western side; this is due to the fact that the great bulk of the ore is found in a pulverised condition, and freed from the presence of silica and other injurious elements, while the deposits referred to on the western side occur in a hard compact condition, requiring much blasting in the operation of mining, and containing a high per centage of silica and carbonate of lime.

On the eastern side of the Forest, adjoining the property of

Messrs. Crawshay, at Cinderford, explorations recently made have attracted some attention. The royalties referred to are those "Gales" or "Setts" previously referred to and known as the Polar Star, Duke of Gloucester, Emperor Napoleon, Berkeley Castle, and Elephant Iron Mines. The annexed analysis of the hematite ore raised in the above gales compares favourably with the best quality of similar ores, not only in the Forest but in other parts of the kingdom:—

RESULTS TABULATED.

Peroxide of iron	82·64
Silica and lime	5·07
Alumina	1·09
Phosphoric acid	1·05
Sulphur	0·06
Loss in calcination	10·68
Total	100·59

The amount of metallic iron contained in the above peroxide is equivalent to 57·85 per cent., while in the calcined ore the metal is concentrated to the extent of 64·77 per cent. The analysis above noted was made in Dr. Percy's laboratory of the Royal School of Mines.

Production of Brown Iron Ore.—The ore raised from the mines of the Forest of Dean is a stalactitic brown hematite, locally known as "Brush Ore;" the more earthy varieties being distinguished as "Smith Ore." The earliest return accessible is for the year 1854, when the production amounted to 85,506 tons, the output of the following iron mines then in operation:—

NAME OF MINE.	WHERE SITUATED.
Buckshraft	Cinderford.
Dean Pit	Clearwell Meend.
New China Level	Noxon Park.
Old Park	Oakwood near Bream.
Old Sling Pit	Lydney Old Park.
Perseverance and Findall	Soudley.
Westbury Brook	Edge Hill, near Mitcheldean.

The returns, since 1854, of the Forest of Dean iron mines are as follows, and side by side appears the distribution in each of the same years, with the quantities used in the iron works:—

Year.	Distribution of the Ore.			Used in Iron-works.	Total of Dean Forest.
	South Wales.	Staffordshire.	Bristol.		
	Tons.	Tons.	Tons.	Tons.	Tons.
1855	20,810	31,042	...	40,756	92,608
1856	39,450	12,000	...	57,818	109,268
1857	49,049	21,773	...	56,732	127,554
1858	34,652	16,288	...	56,712	107,652
1859	22,587	18,524	1,726	63,455	106,292
1860	10,572	11,131	767	67,996	90,466
1861	34,024	483	3,444	62,468	100,419

The total of Dean Forest for the year 1861 includes 1,004 tons carried from the western side of the Forest to the Bullo Pill Junction in that year.

Other deposits of hematite in Gloucestershire, occurring at Frampton Cotterell, near Bristol, were opened out about the year 1861; these deposits occur in the Pennant Grit, an arenaceous rock interposing between the upper and lower coal measures, and have produced ore in the following quantities. The works have been abandoned since the year 1875:—

Frampton Cotterell Mines.

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1862	5,107	1869	6,773
1863	6,000	1870	15,249
1864	11,000	1871	8,487
1865	8,000	1872	9,201
1866	6,000	1873	13,682
1867	6,100	1874	14,842
1868	6,566	1875	8,845

The other places yielding brown hematite in Gloucestershire occur at Iron Acton, Saint Pierre, Hopewell, Noxon Park, High Meadow, and Lydney Park. The three latter on the estate of the Countess of Dunraven, have from time to time produced ore in some quantity. Iron ore is also known to occur at Cotswold, Eldon Redding, Hoxenwall, Midsummer Norton, Pensford, and Temple Cloud, where pits have been sunk, and the ore occasionally worked. The returns of Noxon Park, High Meadow, and Lydney Park Mines, are as follows in the years given:—

Year.	Noxon Park.	High Meadow.	Lydney Park.
	Tons.	Tons.	Tons.
1865	22,000	...	...
1866	19,126	...	...
1867	16,480	...	...
1868	25,093	...	...
1870	30,000	...	...
1871	28,500	...	...
1872	10,000	1,668	15,695
1873	10,000	2,703	12,000
1874	...	4,309	5,950
1875	...	3,500	3,105
1876	6,626	6,755	1,186
1877	4,927	3,944	...
1878	...	561	...
1879	...	299	...
1880	7,028	1,555	...

Following the returns of Dean Forest since the year 1861, up to which time they have been given, it will be convenient to continue the returns published since the year 1862, which enables a comparison to be made of the produce of Dean Forest, and the total ore raised in Gloucestershire, together with the respective values in each year. It will be understood that the total of Gloucestershire includes in each year the produce of the outlying deposits previously referred to. The quantities and values of the ores are as follows :—

Year.	DEAN FOREST.		TOTAL OF GLOUCESTERSHIRE.	
	Quantities.	Value.	Quantities.	Value.
	Tons.	£	Tons.	£
1862	158,908	71,508	164,015	73,806
1863	121,397	54,627	127,497	57,372
1864	130,482	58,723	141,843	63,830
1865	142,807	64,526	152,710	68,983
1866	156,079	70,236	162,129	72,982
1867	156,069	70,231	156,169	70,271
1868	160,722	72,324	167,288	75,333
1869	134,595	60,567	172,023	77,460
1870	138,254	62,214	183,503	82,576
1871	170,611	127,957	207,598	155,060
1872	162,888	122,166	199,453	149,585
1873	163,660	98,196	199,342	125,447
1874	110,203	82,653	171,428	148,910
1875	92,825	62,500	111,825	71,760
1876	98,133	66,285	114,728	77,394
1877	80,555	55,219	92,974	63,261
1878	69,034	41,440	74,761	44,877
1879	52,061	31,237	58,552	35,091
1880	83,198	49,918	92,159	55,174

The value of the ore delivered into trucks at the mines in 1862 did not exceed 9*s*. per ton, increasing to 14*s*. per ton in 1873; as a general average some varieties did not bring more than 10*s*. per ton; in the year 1876 the average was 13*s*. 6*d*., and in 1880 about 12*s*. per ton.

The detailed production of the mines in the last-named year was as follows:—

GLOUCESTERSHIRE IRON MINES, FOREST OF DEAN.

No.	Names of Mines.	Quantities.	Value.
		Tons.	£ *s*. *d*.
1	Buckshraft (Cinderford)	17,641	
2	China Engine (Noxon)	510	
3	Coleford (Coleford)	84	
4	Deans Meend (Mitcheldean)	3,685	
5	Easter (Coleford)	8,994	
6	Forget-me-not (Bream)	200	
7	Lambsquay (Clearwell Meend)	167	
8	Lydbrook	6	
9	New China Level (Noxon)	4,372	
10	New Dun Pit	213	
11	Oak Pit	131	
12	Old Ham Pit (Clearwell Meend)	1,071	49,918 6 0
13	Old Row Pit	16	
14	Oakwood Mile (Noxon)	3,233	
15	Old Sling Pit (Clearwell Meend)	9,986	
16	Old Park (Bream)	1,008	
17	Parkhill (Lydney)	596	
18	Perseverance (Newnham)	1,537	
19	Saint Annals (Bream)	4,621	
20	Shraves ,,	592	
21	Slope Pit	983	
22	Westbury Brook (Mitcheldean)	12,413	
23	Wigpool Belt ,,	10,750	
24	Yew Tree (Bream)	389	
	Total of Forest of Dean Ore	83,198	49,918 6 0
25	Highmeadow (Coleford)	378	106 16 0
26	Ringwell and Gattell	1,555	933 0 0
27	Noxon Park (Bream)	7,028	4,216 6 0
	Total of Gloucestershire	92,159	55,174 8 0

Before considering the distribution of the Forest of Dean hematite, it will interest those familiar with the district and connected with its mining operations to have for convenient reference reliable data, showing the produce of some of the more important mines in the Forest. With this object in view, the following abstracts have been prepared, showing the annual produce of the

mines named, and giving the returns as far back as possible. The first group to which attention is directed includes those mines in the neighbourhood of Cinderford, on the eastern side of the Forest, from which mines the blast furnaces of the district have received their supplies of hematite; they are as follows:—

Year.	Buckshraft.	Findall, &c.	Westbury Brook.
	Tons.	Tons.	Tons.
1863	44,219	9,678	13,659
1864	39,770	9,416	20,501
1865	46,127	13,947	33,822
1866	48,735	10,738	35,495
1867	48,659	15,079	21,810
1868	47,649	14,983	28,060
1869	42,096	11,443	25,825
1870	38,639	8,471	26,352
1871	37,694	8,117	16,005
1872	34,409	3,939	14,693
1873	30,706	4,472	14,112
1874	15,531	9,239	25,200
1875	21,008	...*	12,518
1876	21,139	8,245	23,798
1877	17,783	9,020	10,976
1878	27,212	3,077	17,781
1879	19,041	...	8,730
1880	17,641	...	12,413

Turning to the western side of the Forest, in the district of Clearwell Meend, the mines have produced hematite in the following quantities:—

Year.	Clearwell.	Old Bow Pit.	Easter.
	Tons.	Tons.	Tons.
1863	1,309	...	11,398
1864	4,693	...	9,495
1865	...	...	4,548
1866	306	...	5,728
1867	1,254	...	10,435
1868	2,151	2,981	10,409
1869	4,925	4,317	11,013
1870	1,765	6,691	9,968
1871	4,861	5,181	17,619
1872	3,858	7,131	14,726
1873	5,331	5,230	13,675
1874	3,255	3,234	7,077
1875	2,330	257	6,974
1876	2,331	682	7,633
1877	340	631	3,345
1878	602	184	1,859
1879	...	...	1,559
1880	...	16	8,994

* No return.

A falling off appears in the output of the above mines, due to the depressed condition of the iron industries of late years.

The following mines in the neighbourhood of Lydney and Coleford gave tonnages as follows in each of the years named :—

Year.	LYDNEY.			COLEFORD.
	Oakwood.	Old Sling.	Shraves.	Crow's Nest.
	Tons.	Tons.	Tons.	Tons.
1863	4,227	16,904	380	300
1864	5,145	15,940	1,095	4,868
1865	6,484	12,380	553	...
1866	8,742	8,519	819	158
1867	10,251	11,585	866	5,342
1868	2,981	9,952	431	1,109
1869	3,018	4,671	175	4,790
1870	6,804	6,887	756	5,390
1871	6,858	6,285	823	5,782
1872	8,750	7,233	2,295	4,404
1873	9,960	4,988	2,704	5,230
1874	5,445	5,916	2,341	870
1875	2,121	6,455	863	...
1876	765	5,543	505	...
1877	408	3,603	689	...
1878	4,334	3,479	102	...
1879	3,501	881	57	...
1880	3,233	9,986	592	...

The Deen's Meend Mine of the Dowlais Iron Company, situated near Mitcheldean, and the Wigpool and Saint Annal's Mines, the last-named situated near Cinderford, produced the following quantities in each of the years named :—

Year.	Wigpool.	Deen's Meend.	Saint Annal's.
	Tons.	Tons.	Tons.
1863	...	13,180	...
1864	...	14,768	...
1866	402	12,233	...
1867	124	8,421	...
1868	122	9,813	...
1869	...	8,622	...
1870	6,815	6,231	...
1871	19,792	5,336	3,214
1872	11,729	3,256	9,811
1873	22,106	3,491	10,874
1874	...	3,555	9,620
1875	6,844	2,580	11,112
1876	4,378	2,686	3,806
1877	10,535	2,490	...
1878	2,665	2,810	...
1879	2,848	2,585	...
1880	10,750	3,685	4,621

Distribution of the Forest of Dean Ore.—The early returns showing the distribution of the ore to the year 1861, being intimately associated with the production, have already appeared. It will now be desirable to follow the inquiry, and note for subsequent years the quantities sent into other iron-making districts, notably South Wales, Staffordshire, and Somersetshire, distinguishing the quantities retained in the Forest for consumption in the ironworks:—

Year.	South Wales.	Staffordshire.	Bullo Pill Junction.	Bristol.	Used in Forest.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1862	49,718	978	8,617	...	99,595	158,908
1863	45,946	665	13,450	...	61,336	121,397
1864	51,210	32	14,741	335	64,164	130,482
1865	43,152	...	9,170	3,354	87,131	142,807
1866	57,904	...	6,000	2,074	90,101	156,079
1867	53,114	...	...	1,644	101,311	156,069
1868	50,068	251	...	...	110,403	160,722
1869	29,794	...	...	...	104,801	134,595

Of the ore raised in the Forest of Dean, the respective quantities sent from the eastern and western sides appear as follows for each of the years given:—

Year.	Eastern Side.	Western Side.	Total.
	Tons.	Tons.	Tons.
1856	55,450	53,818	109,268
1857	56,475	71,079	127.554
1858	71,098	36,554	107,652
1859	62,557	43,735	106 292
1860	46,661	43,805	90.466
1861	64,758	35,661	100,419
1862	98,431	60,477	158.908
1863	94,601	26,796	121,397
1864	95,858	34,624	130.482
1865	108,985	33,822	142.807
1866	109,503	46,576	156,079
1867	123,838	32,231	156 069
1868	50,649	110,073	160,722
1869	34,407	100,188	134,595

In the above returns, the ore consumed in the iron furnaces for the years 1868 and 1869 is included in the western side, while in previous years it is included in the eastern side of the Forest.

Since the year 1869 the Severn and Wye Railway have forwarded ore in the following quantities :—

Forwarded.	1870.	1872.	1873.	1874.	1875.
	Tons.	Tons.	Tons.	Tons.	Tons.
By Water to Wales	21,277	35,540	12,632	2,233	...
By Rail to Wales	15,734	12,154	...	26,437	12,864
By Rail to Bullo Pill	14,291	12,057	43,252		1,445
By Rail to Staffordshire	12	3,855	...		250
By Water to Bristol	148	446	150		...
By Water to Gloucester	...	3,389	728		...
Total	51,462	67,441	56,762	28,670	14,559

In the year 1876, and since, the distribution of ore appears in the following quantities by the Great Western Railway :—

YEAR.	GREAT WESTERN.
	Tons.
1876	73,286
1877	73,236
1878	56,111
1879	37,586
1880	45,014

In the year 1876 the Severn and Wye Railway carried out of the district 8,005 tons.

Pig Iron Manufacture.—The Forest of Dean has for many centuries been associated with the iron manufactures of Great Britain, in many localities in the Forest, near the sites selected by the Romans for the erection of their altars dedicated to Mars, the god of battle, numerous remains of scoriæ or slags have been found, and containing so large an amount of metallic iron, that for many generations it has been found profitable to re-smelt them. In other districts in this country similar remains have been discovered—as, for example, at Bierley, near Bradford, in the West Riding of Yorkshire, and again on the Brendon Hills, in Somersetshire. It is stated that during a period of three centuries about 20 small charcoal furnaces existed in the Forest of Dean, engaged in the re-smelting of these rich slags, said to contain from 30 to 40 per cent. of metallic iron. It is no less remarkable that it was on the hills that these Roman slags were invariably discovered, leading to the inference that bellows were not then employed, but that the furnaces were so constructed as

to utilise the wind by suitable channels, through which it was conducted, always taking advantage of the natural currents. These furnaces, or air bloomeries, were hollows dug out at the top of a hill, with covered channels leading to the hillside in the direction of the prevailing wind, which would blow through them into the fire, the latter being kept up with wood or charcoal, the iron ore being introduced into the burning mass. The early process thus referred to was of a very primitive character, and was attended with very great loss of metallic iron remaining in the rejected slags. Similar air furnaces, it is stated, were employed in Derbyshire in the 17th century for the reduction of the ores of lead. As soon as bellows were introduced, about the 8th century, a new impulse was given to the iron industries generally; instead of hollows these so-called bloomeries were built up walls, which were gradually heightened till they attained an elevation of from 5 to 6 feet, the diameter also augmenting to 3 and 4 feet, thus becoming wolf furnaces, and furnaces of this description were employed in America and Hungary until less than 100 years ago, and are now in use at the present time in the East, in India and Turkey. Originally these furnaces were rectangular in form, but after the 16th century they became elliptical, and eventually in the last century circular in section. They were not, however, in such a condition as to produce a fusible cast iron, as they could only deliver lumps, "wolves," or pigs of half malleable wrought iron. Previous to the introduction of bellows, as already stated about the 8th century, we find the valleys selected for the sites of blast furnaces or bloomeries, where water power was obtainable, and could be made available as a motive power in impelling the blast; with this change the manufacture was carried on under more favourable circumstances.

In the Forest of Dean, about the beginning of the 16th century, charcoal blast furnaces, it appears, were introduced from the iron districts of the Rhine; these furnaces were 6 feet wide at the boshes and 15 feet high, and we have the authority of Mr. David Mushet, who found the remains of two such furnaces, having probably been built during the reign of Edward VI., and about the year 1550. Again, in the reign of Elizabeth, it is known that the art of iron casting had in this country attained a certain degree of perfection, as cast-iron ordnance were then largely exported to the Continent, and the annual production of charcoal

pig iron at this period was estimated at not less than 180,000 tons per annum. The great drain on our forests at a subsequent period to furnish the fuel—charcoal—for the reduction of the ores of iron in the blast furnace, nearly brought the iron industries of England and Wales to a standstill; indeed, not less than three-fourths of the blast furnaces then erected were inactive. As a matter of history, it may be here stated that Oliver Cromwell was an ironmaster in the Forest of Dean about the middle of the seventeenth century.

Not until the year 1740 have we any information to refer to, showing the production of pig iron in the Forest of Dean, although ample evidence exists of the industry being carried on at a very much earlier period. Dealing, however, with the statistical facts available for the year 1740, we find in Gloucestershire, presumably in the Forest of Dean, four furnaces producing 800 tons of charcoal pig iron, being an average make of 200 tons per furnace. At this period the production of charcoal pig iron in Great Britain amounted to 17,350 tons, the make of 59 furnaces. Charcoal continued to be used in the Forest of Dean furnaces, for in the year 1788 we find four furnaces in operation, producing 2,600 tons, giving an average yield of 650 tons per furnace. In this last-named year 24 furnaces using charcoal were in operation in England and Wales, making 13,100 tons of iron, and 53 furnaces using coke making 48,200 tons of iron, or a total make in 1788 of 61,300 tons of pig iron, to which should be added the production of Scotland, amounting to 5,600 tons of coke pig, and 1,400 tons of charcoal pig iron; the Scotch furnaces being those of the Carron Company, and other works situated at Wilsonstown and Cleugh. The total iron made in Great Britain at this time, 1788, being 68,300 tons.*

Advancing to the year 1796, the only furnaces in operation were situated at Flaxley, and produced in that year 380 tons of pig iron; the number of blast furnaces in England and Wales being 104, and the production of pig iron 167,321 tons, while in Scotland the same year 17 furnaces produced 16,086 tons, giving the total yield of the furnaces of Great Britain as 183,407 tons.

At the end of the last and beginning of the present century it is quite certain the iron industries of Great Britain were far from

* For details, see Appendix II., p. 831.

being in a prosperous condition; indeed, it is stated by some writers that at the period referred to, the iron trade of the Forest of Dean was nearly at a standstill. Other periods of depression ensued, while in later years more prosperous times succeeded, and when about the year 1826 the works and furnaces at Parkend commenced operations, a new era was inaugurated. The Parkend works were projected and carried out by Mr. Moses Teague, who at a later period established the works at Cinderford. The above-named gentleman has the distinction of being the chief agent in promoting the successful development of the iron industries of Dean Forest. Considerable obscurity surrounds the progress of iron manufacture in the Forest between the years 1796 and 1839. In the last-named year the furnaces in operation were those of the Parkend and Cinderford companies, the former having three, and the last-named, two blast furnaces at work, producing 18,000 tons of pig iron, giving an average yield of 3,600 tons per furnace. The return here referred to was prepared by Mr. David Mushet, who made in the same year a survey of the iron industries of the United Kingdom, ascertaining the number of furnaces in operation as 396, and the production of pig iron 1,248,781 tons.*

Again, in the year 1840 the four furnaces in operation in the Forest produced 15,500 tons. From the investigation made in the same year by Mr. William Jessop, of the Butterley Ironworks, who pursued his inquiries to all the iron-making districts of Great Britain, it was ascertained that of the 490 furnaces built 402 were in blast, making 1,396,400 tons of pig iron, and consuming 4,877,000 tons of coal in its manufacture.

Advancing to the year 1851, the total production of pig iron in the five furnaces working amounted to 30,000 tons. At this period the Darkhill and Oakwood Vale furnaces were in course of erection; the former by Messrs. Mushet, the latter by the Ebbw Vale Iron Company; and in the year 1855 the works at Soudley were erected by Mr. B. Gibbons, junr. In subsequent years the furnaces built and in operation, with the production of pig iron and average make per furnace, appear as follows, the production increasing from 21,990 tons in 1854 to 34,927 tons in 1863, and the average make per furnace from 4,395 tons to 5,821 tons :—

* For details, see Appendix II., p. 835.

Year.	Furnaces.		Pig Iron Made.	Make per Furnace.
	Built.	In Blast.		
			Tons.	Tons.
1854	7	5	21,990	4,395
1855	7	4	19,500	4,975
1856	10	5	24,132	4,826
1857	10	5	23,882	4,776
1858	10	4	23,580	5,895
1859	10	6	31,750	5,292
1860	9	4	26,458	6,614
1861	9	3	23,163	7,721
1863	9	6	34,927	5,821

Since the year 1863, and until 1871, the production of the Forest of Dean furnaces are included with the furnaces of Wiltshire and Somersetshire, and appear in the following table :—

Year.	Forest of Dean.		Wiltshire.		Somersetshire.		Pig Iron.
	Furnaces.		Furnaces.		Furnaces.		Total.
	Built.	In Blast.	Built.	In Blast.	Built.	In Blast.	
							Tons.
1864	9	6	3	3	2	1	65,312
1865	9	6	3	3	2	1	65,471
1866	10	6	3	3	2	1	59,817
1867	10	6	4	3	2	1	71,186
1868	10	6	4	3	2	1	75,847
1869	10	6	4	3	2	1	81,306
1870	10	7	5	4	2	1	93,601
1871	9	7	7	5	2	1	99,997

In the year 1872, and following years, the production of the Forest of Dean furnaces is separately distinguished, and appears in the annexed table; side by side the average yield of each furnace is given :—

Year.	Furnaces.		Pig Iron.	Average per Furnace.
	Built.	In Blast.		
			Tons.	Tons.
1872	10	6	46,226	7,704
1873	10	6	44,049	7,341
1874	10	6	43,139	7,186
1875	10	6	27,088	4,514
1876	10	5	28,108	5,621
1877	9	4	25,602	6,400

In the years 1878, 1879, and 1880, the yield of the Forest of Dean furnaces did not exceed 15,000 or 16,000 tons; those in operation being the Cinderford Works, of Messrs. Henry Crawshay & Co., the production of which is included in the returns of Wiltshire and Somersetshire.

The Ebbw Vale Company's Works at Oakwood, it may be noted, were a few years since closed, and the furnaces dismantled. The works in Gloucestershire in 1880, with the names of the companies and number of furnaces built and in blast, were as follows:—

No.	Names of Works.	Owners.	Furnaces.	
			Built.	In Blast.
1	Cinderford . . .	Henry Crawshay and Co. . .	4	2
2	Park End, Lydney . .	Forest of Dean Iron Co., Limited	3	0
3	Great Western, Soudley.	Great Western Iron Co., Limited	2	0
	Total of Gloucestershire		9	2

Malleable Ironworks, Mills, and Forges.—The early history of the Malleable iron trade is more or less historically identified with the early records of the Forest of Dean. According to Scrivenor, in his "History of the Iron Trade," it appears probable that shortly after the Emperor Adrian visited this country (A.D. 120), accompanied by the sixth legion of Roman soldiers, a great military forge—Fabrica—was by his direction established at Bath, for the purpose of manufacturing war implements for the various troops in Britain, and for some bodies of Roman soldiers on the Continent. This branch of manufacture was of considerable importance at that time, and the regulations for the management of the Fabrica, or College of Armourers, were most systematic and complete. The iron used for the manufacture of the military weapons at this establishment is supposed to have been obtained from the Forest of Dean and the hills of Monmouthshire, where the ore was dug up and smelted, the iron taken across the Severn at Lydney, landed at Aust, and taken to Bath by a military way almost parallel with the Upper Bristol Road. Again, we have it on the authority of the Domesday Book that bolts and bars of iron required by King Edward's shipbuilders were obtained from the city of Gloucester, which from its close proximity to the Forest

of Dean reasonably induces to the inference that they were produced there.

Slags and cinders occur in various places in the Forest of Dean and in the Brendon Hills, in which pottery and Roman coins have been discovered, tending to establish the fact of the existence at an early period of ironworks and foundries, in which charcoal had alone been employed. It also appears that at an early period the monks of Flaxley, located in the Forest of Dean, established forges in various places where wood, iron ore, and water were abundant, power being secured for the primitive mechanical appliances then in use, by the flowing streams in the sites selected.

From an original document in the possession of Samuel Timmins, Esq., of Birmingham, and supposed to have been prepared about the middle of the last century, 1750, we learn that about that period there were five works in operation in Gloucestershire, producing 1,120 tons of bar iron per annum. The works were as follows, with the individual production of each:—

NAME OF WORKS.	MAKE OF BAR IRON. Tons.
Lidney	350
Lidbrook, Three Forges	350
Upleaden	120
Tortworth	150
Flaxley	150
Total	1,120

More recently, in the beginning of the present century, about the year 1805, the principal works existing were situated at Froombridge, in the parish of Frampton, where iron and brass wire was made, and at Framilode, in the parish of Eastington, a manufactory of tin-plate was in operation. Again, at Flaxley and at Lydney works of an extensive character are known to have been in existence, both for the reduction of the ores of the district and the manufacture of malleable iron, the first-named of the above works having then, as now, the reputation of making iron of a character known as "red short," especially celebrated and in great request for the manufacture of tin-plate. The works at present and for many years in operation in the Forest of Dean are those at Park End, formerly belonging to the Forest of Dean Iron Company, and now to Messrs. Crawshay and Sons, consist-

ing of three puddling furnaces and two rolling mills, and the works of the Great Western Iron Company, Limited, situated at Soudley, with one rolling mill.

Coal and Iron Ore used in Manufacture.—Mr. William Jessop, of the Butterley Ironworks, a gentleman previously referred to as being intimately acquainted with the iron industries of Great Britain, ascertained that in the year 1840, in Dean Forest, the quantity of coal consumed in the manufacture of each ton of pig iron was 67 cwts. The Royal Coal Commission, in the year 1869, after a careful inquiry, found that the consumption did not exceed 66 cwts.

Since the year 1872 the exact proportions have been ascertained and appear as follows, of pig iron made and of coal and ore used in its manufacture:—

Year.	Pig Iron.	Coal Used.	Iron Ore.
	Tons.	Tons.	Tons.
1872	46,226	125,461	119,485
1873	44,049	134,019	94,019
1874	43,139	137,413	92,150
1875	27,088	87,051	75,975
1876	28,108	89,318	79,541
1877	25,602	77,196	68,520

The quantities of hematite above referred to are exclusively the produce of the Forest mines; other ores are employed, also a small proportion of mill cinder; of these latter the quantities are not considerable. Taking the ores throughout, including the mill cinder used, the average employed varies from 55 to 60 cwts. to each ton of pig iron made. In the preparation of these ores before smelting it is usual to subject them to the process of roasting or calcination, by which the metal is concentrated into a smaller weight by the removal of water, carbonic acid, &c.

In the higher class of hematite ore raised from the Forest of Dean mines, the iron is concentrated by calcination to the extent of from 10 to 12 per cent., the fragments being rendered more porous and susceptible of change in the subsequent operations of smelting in the blast furnace.

Taking the consumption of coal in pig iron manufacture in the Forest of Dean, the average may be generally regarded as slightly in excess of 61 cwts. of coal to each ton of pig iron made; the

ores of all kinds, as already stated, varying from 55 cwts. to 60 cwts. to each ton of pig iron made. For a few years the details in the annexed table show the quantities of ore conveyed to the several ironworks for reduction since 1856 :—

Year.	Cinderford.	Parkend.	Soudley.	Total.
	Tons.	Tons.	Tons.	Tons.
1856	28,000	29,818	...	57,818
1857	29,000	27,732	...	56,732
1858	40,000	16,712	...	56,712
1859	44,000	17,655	1,800	63,455
1860	43,700	16,796	7,500	67,996
1861	42,300	19,640	528	62,468
1862	64,625	17,100	17,870	99,595
1865	...	...	...	87,131
1867	61,311	30,000	10,000	101,311
1869	54,793	38,508	11,500	104,801
1871	60,000	52,725	20,600	133,325
1872	51,748	44,137	23,600	119,485
1873	...	...	...	74,019
1874	...	...	...	92,150
1875	...	...	...	75,975
1876	...	...	...	79,541
1877	...	...	...	68,520
1878	...	...	...	41,312
1879	...	...	...	47,000
1880	...	...	...	*

From the above table it will be seen that from 1867 to 1872 was a period of great activity, since which latter year a great falling off is shown.

* Not ascertained.

CHAPTER XVII.

SOMERSETSHIRE IRON INDUSTRIES.

Description of the Spathose Iron Ore Deposits of the Brendon and Eisen Hills—Early explorations at Gupworthy Mine—Analyses and Production of Iron Ore—Pig Iron Manufacture—Mills and Forges.

Iron Ore Deposits of the Brendon Hills.—The district known as the Brendon Hills extends nearly east and west at about six miles south of that part of the coast in the Bristol Channel lying between Watchet and Minehead, and terminates in a deep valley near Eisen Hill, where deposits of iron ore also occur. The Brendon Hills rise boldly on the north side, but on the south side the decline is easier, and they merge into numerous small valleys and gentle elevations; the highest ground in this range of hills is about 1300 feet above the level of the sea. The variety of iron ore occurring in the Brendon and Eisen Hills is that known as Spathic, or carbonate of iron, and brown iron ore; it is also known as Siderite, and forms an important ore and source of metal.

These spathic ores are rich in manganese and valuable for conversion into spiegeleisen; the only other deposits of this kind known to exist in this country are those of Weardale in Durham, where the ore is associated with ores of lead and zinc, at Exmoor in North Devon, the Exmouth and Frank Mills mines near Exeter, the Duchy and Peru, and Perran mines in Cornwall.

The ferruginous deposits of the Brendon Hills occur in the upper division of the middle Devonian rocks, known as Morte slates, composed of clay slate. At the surface the clay slate is of a greyish colour, but in depth it invariably acquires a blue or greenish colour. At a distance of two miles north of the most elevated part of the hills at Treborough, lower beds of this slate (Ilfracombe type) associated with limestone are extensively

quarried, and yield a good roofing material. The ore wrought in the Brendon Hills may be generally referred to the following varieties: first, a "white ore," a spathose ore, generally crystalline in character; secondly, a red ore consisting of decomposed spathose; and thirdly, other varieties known as "black ore," "brown ore," and "potty ore," composed of dark brown ores, more or less cellular.

The above varieties occur in the form of pockets, which sometimes exist in close proximity to each other, admitting of their being worked from one mine. The term "lode," it should be observed, in this district is applied to any metalliferous part of a vein, while the unproductive parts of the lode are said to be "dead;" again, when the sudden enlargement of a lode or pocket takes place, it is designated a bunch of ore.

Numerous indications of old workings in the Brendon Hills point to the fact of there having been extensive explorations in ancient times; it is, however, within the last twenty-five years that they have been opened up on a large scale, growing from insignificant workings to important mines. The iron deposits of the Brendon Hills are the property of the Ebbw Vale Company, the ore raised from the mines being sent to the works of the Company in Monmouthshire.

The most ancient workings appear at the eastern end of the Brendon Hills, known as the Colton Pits, and were wrought horizontally of a zig-zag form; further to the east these old workings are again met with, clearly showing that the ancient miners selected localities in which the ore existed most abundantly; further to the west the Roman and Carew mines occur; these have of late years been further explored and worked on a limited scale. Taking a westerly direction, is the Raleigh Cross Mine, situated and adjoining the Carnarvon Mine, with which it is connected by a heading; the first drift sunk on the lode at the Carnarvon Mine did not reveal a favourable condition; later, in the year 1866, a new drift was commenced, and the more productive part of the lode was opened. Other workings appear to the west at the Burrow Mine, near Wiveliscombe; the ore here wrought is at times hard and red, and occasionally possesses a rich blue colour. The next workings are those at Florry Mine, where the ancient workings were found to have a depth of 30 feet, below which the lode appears to yield a hard red ore; again, in the Bearland Wood

Mine to the west, are found some extensive explorations, the lode yielding large quantities of a soft red ore.

The Gupworthy Mine was the first opened in the Brendon Hills of which there is any account, and it appears to be the locality from which the first undecomposed spathose ore was obtained. Mr. Morgan Morgans, in an interesting paper on the Brendon Hills spathose iron ores and mines, read before the South Wales Institute of Mining Engineers, in 1868, gives the following account of the history of the discovery which led to the development in the Brendon Hills :—" Many years ago a Mr. Tibbets, of Cornwall, being convinced from the nature of the ground, old surface workings, and small mineral specimens found in the latter, that a copper lode existed below, began exploration by driving an adit at Gupworthy. This adit intersected the iron lode, which at this point (20 fathoms deep) was very excellent, compact, and undecomposed spathose.

" Some years later the deposits of the Brendon Hills attracted the attention of the late Mr. Ebenezer Rogers, of Abercarne, who was struck with the similarity of the continental ores and those raised at Gupworthy, a collection of which had been previously made and exhibited in the Great Exhibition of the year 1851 from this and other districts. He subsequently more fully explored the deposits, ascertaining their extent and importance, and eventually transferred his interest to the Ebbw Vale Iron Company, who set to work vigorously and developed the deposits, a considerable portion of the lode of which had a thickness of 20 feet. Further to the west explorations were made at Kennesome Hill and Goose-Moor Mines in the Brendon Hills, beyond which ore has not hitherto been wrought to any extent, until Eisen Hill is reached, where, as previously stated, valuable pockets of ore occur."

Analyses of the Spathose Iron Ore of the Brendon Hills.— This ore, especially rich in manganese, has attracted considerable attention of late years, the pig iron made therefrom being of excellent quality, and suitable for conversion into Bessemer steel. The ore has been examined by Mr. John Spiller, and is found occasionally streaked with red hematite. At the outcrop of the veins the spathose ore is invariably found to be converted to a considerable depth into brown hematite by the influence of air and water. The following shows the composition of the ore :—

RESULTS TABULATED.

Protoxide of iron	43·84
Protoxide of manganese	12·64
Peroxide of iron	0·81
Lime	0·28
Magnesia	3·63
Carbonic acid	38·86
Total	100·06

The equivalent of metallic iron determined by the above analysis is 34·65 per cent., and of manganese 9·73 per cent.; the spathose ore of Weardale giving 38·56 per cent. of metallic iron, and 1·86 per cent. of manganese.

The ore by calcination exhibits the following constituents, the loss in weight by the process being equivalent to 34·29 per cent.:—

RESULTS TABULATED.

Magnetic oxide of iron	47·87
Sesquioxide of manganese	14·06
Lime	0·28
Magnesia	3·63
Insoluble residue	0·08
Loss by calcination	34·40
Total	100·32

The metallic iron contained in the calcined ore is equivalent to 34·16 per cent. The following analyses, composed of a burthen of Brendon Hills ore and Welsh Mine, is given by Dr. Percy in his "Metallurgy of Iron and Steel," the yield of metallic iron representing 32·18 per cent. The details of analysis are as follows:—

RESULTS TABULATED.

Protoxide of iron	41·03
Peroxide of iron	0·41
Protoxide of manganese	0·55
Alumina	5·79
Lime	3·00
Magnesia	3·36
Potash	0·86
Silica	13·35
Carbonic acid	28·49
Phosphoric acid	0·70
Water	1·93
Organic matter	0·07
Total	99·54

The calcined ore of the Brendon Hills is concentrated to the extent of 51 per cent. in the raw state, it varies between 34 and 35 per cent. Thus, to make a ton of pig iron, 2·89 tons of raw ore would be required, while in the calcined state 1·96 tons would be the quantity required. Mr. John Spiller, who has carefully examined these ores, in Dr. Percy's laboratory, gives the following elementary analysis of the ore after calcination, including the insoluble residue :—

RESULTS TABULATED.

Metallic iron	50·9971	combined with oxygen	21·8559
,, manganese	14·9130	,,	6·4840
,, calcium	0·3044	,,	0·1222
,, magnesium	3·3150	,,	2·2100
,, silica	0·0509	,,	0·0549
,, aluminium	0·0079	,,	0·0069
Oxygen . .	30·7739	,,	30·7339
Total .	100·3622		

The ore thus calcined is sufficiently rich in manganese to yield a spiegeleisen containing 20 per cent. of that metal.

Production of Iron Ore in Somersetshire.—The spathic ores of the Brendon Hills are worked extensively, as they have been for some years by the Ebbw Vale Iron Company. The ore raised from the mines is conveyed by railway to the coast, shipped to Newport in Monmouthshire, and forwarded from that port to the works of the Company for reduction. The ore was originally obtained from the Carnarvon and Raleigh Cross Mines and shipped from the district; but about the year 1864 a line of railway was constructed over the hills, from the top of the Brendon Hills to Gupworthy, giving increased facilities for sending the ore out of the district. Iron ore has also been raised from time to time at Yatton, Winford, and in the Mendip Hills, being distributed by the Bristol and Exeter Railway for shipment to Bristol, Highbridge, and Bridgewater. The following statement shows the production of the Somersetshire mines from 1855 to 1858 inclusive :—

Year.	Brendon Hills.	Yatton.	Winford.	Bristol.
	Tons.	Tons.	Tons.	Tons.
1855	4,940	...	...	...
1856	7,620	5,000	1,500	500
1857	9,642	6,000	1,200	7,500
1858	19,018	767	...	1,200

The ore raised at Yatton, Winford, the Crescent at Bristol, and Ashton Hill Mines, is brown hematite, that at Ashton Vale, clay ironstone from the coal measures.

In the year 1858, quantities in addition to the above were produced, namely, at Honeymead, 2,000 tons; Ashton Vale, 2,616 tons; and Ashton Hill, 2,000 tons. The total production of all varieties of ore in each of the above years was 4,940 tons in 1855, increased in 1856 to 14,620 tons, in 1857 to 25,342 tons, and 26,041 tons in 1858, the value at the place of production in the last-named year being about 10*s*. per ton.

In subsequent years the mines of Somersetshire produced ore in the following quantities:—

Year.	Brendon and Eisen.	Yatton.	Ashton Vale.	Ashton Hill.	Bristol.
	Tons.	Tons.	Tons.	Tons.	Tons.
1859	23,183	1,580	2,000	750	1,507
1860	18,072	569	3,960	...	1,500
1861	23,787	175	7,300	...	1,500
1862	29,321	...	342	...	1,750
1864	36,385	74	12,965	*	3,500
1865	27,541	...	6,348	620	3,475
1866	29,468	...	2,720	635	2,500
1867	32,525	...	2,350	...	2,000
1868	27,925	...	2,760	...	1,765
1869	23,458	...	1,646	626	1,500
1870	14,603	...	2,110	2,051	975
1871	27,556	...	1,673	2,654	1,000
1872	27,913	...	...	2,000	1,000
1873	28,982	...	620	15,800	1,012
1874	38,316	...	952	...	500
1875	41,793	1,674†	1,015	...	550
1876	41,351	2,761†	...	...	...
1877	46,895	5,033‡	...	...	...
1878	40,115	...	...	...	...
1879	14,100	...	...	...	...
1880	27,668	...	...	...	...

The aggregate returns of production of iron ore in Somersetshire as detailed in the above abstract, a few occasional parcels being omitted, appear in the following total, with the value in each year at the place of production, the years of greatest production being 1873 and 1877, increasing from 46,532 tons in the former to 51,927 tons in the last-named year:—

* Included in Ashton Vale return.

† Winford Mines (a variety of ore known as paint ore).

‡ Including Winford and Exford Mines.

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1857	25,342	12,671	1869	27,230	7,980
1858	26,041	13,020	1870	19,739	6,908
1859	29,083	14,501	1871	32,883	32,883
1860	24,101	12,450	1872	30,913	30,163
1861	32,763	16,381	1873	46,532	42,149
1862	31,443	15,182	1874	41,342	30,588
1863	34,709	17,354	1875	45,166	33,186
1864	54,925	26,868	1876	44,299	31,110
1865	37,984	18,992	1877	51,927	36,348
1866	35,323	17,661	1878	43,115	30,180
1867	36,875	17,952	1879	14,100	10,147
1868	32,450	12,168	1880	29,318	23,127

The average value of the ores from 1858 to 1867 appears to be about 10*s*. per ton; during the years 1871 and 1872 a period of commercial prosperity reigned, not only in the iron and coal, but in other industries, and at this period the value of the ore was greatly augmented, averaging 20*s*. per ton. Since that date a gradual diminution in value is apparent; thus, in the year 1874, the average price per ton was nearly 15*s*., receding in the year 1876 to 14*s*., since which the same price may be said to have ruled.

The mines producing iron ore in Somersetshire in 1880 are given in the annexed table, with the respective quantities and value:—

No.	District or Mine.	Character of Ore.	Quantities.	Value.
			Tons.	£ s.
1	Brendon Hills . . .	Spathose . .	27,668	22,134 8
2	Dolberrow (Lyncombe) .		450	270 0
3	Harptree, E. & W. (Mendips)	Brown Hematite	100	60 0
4	Michael Hobbs (Winford) .	,,	925	555 0
5	Tallards (Winford) . .	,,	125	78 0
6	Tarn (Winford) . . .	,,	50	30 0
	Total of Somersetshire		29,318	23,127 8

Pig Iron Manufacture.—About the year 1857 works were erected at Pennywell Road, near Bristol, by Messrs. Langford & Co., commencing the make of pig iron; the quantity made did not exceed 300 tons, the furnace being in blast but a few months; in the year 1858 the make of the furnace increased to nearly 5,000 tons. In the following year the works at Ashton Vale were

projected by Messrs. Knight & Co., and in 1860 produced 1,960 tons of pig iron. The Pennywell Road Works were for many years standing, and finally abandoned about the year 1865. The returns of production of the Ashton Vale Works in subsequent years until 1871 are included in the Gloucestershire returns, and until 1876 in the Wiltshire returns, since which the works have been standing. The malleable iron works, mills, and forges are represented in Somersetshire, by the establishment at Ashton Vale,* conducted by Mr. Joseph Tinn, and possessing 10 puddling furnaces and 3 rolling mills.

* Standing in 1880.

CHAPTER XVIII.

WILTSHIRE, DORSETSHIRE, OXFORDSHIRE, BUCKINGHAMSHIRE, HAMPSHIRE, AND THE ISLE OF WIGHT IRON INDUSTRIES.

Iron Ore Deposits of the Lower Greensand, Coral Rag, and Marlstone rocks of these Counties—Analyses and Production of Ore—Pig Iron Manufacture in Wiltshire, at Westbury and Seend—Production of Pig Iron in Wiltshire (including Gloucestershire and Somersetshire)—Charcoal Pig Iron Manufacture in Hampshire—Coal and Iron Ore used in Manufacture.

Wiltshire and Dorsetshire Iron Ore Deposits.—The form of iron ore known as brown hematite, existing abundantly in this country in the Lias, Oolitic, and Lower Greensand formations, has in recent years given rise to the important iron-producing districts of Middlesborough, Lincoln, Northampton, and Wiltshire. These extensive deposits extend almost continuously from the northern parts of Wiltshire, in the south of England, to the East Riding of Yorkshire, passing through the counties of Oxford, Buckingham, Northampton, and Lincoln. The ores are for the most part of an impure and sandy character, inexpensively wrought and largely employed in admixture with other ores in South Wales, Derbyshire, and Staffordshire.

In Wiltshire the principal deposits of ore occur at Westbury, Seend, and Heywood. At Westbury and at Heywood, in the coral rag, a division of the Middle Oolite; at Seend in the Lower Greensand. The coral rag consists of beds of fossiliferous limestone, containing corals and shells generally in a fragmentary state; the thickness of the deposit at Westbury, where the iron furnaces are erected, is about 15 feet, and it has been traced from the junction of the Salisbury branch of the Great Western Railway to Warminster, which is below the Westbury station, up through Steeple Ashton in Oxfordshire, by Rowde, north of Devizes, and to Kemby, the high ground south of Chippenham.

At Seend, the deposits of iron ore, as previously stated, occur

in the Lower Greensand formation, and are very similar in character to the ores raised in the north of France, in the neighbourhood of Marquise, which are smelted at the ironworks at Outreau, on the river Lianne, near Boulogne. The deposits at Seend are said to occupy an area of 150 acres and upwards, containing an enormous mass of ore, and easily wrought with a pick and shovel; the overburden in some places not exceeding 1 or 2 feet, which is easily removed, enabling the ore to be wrought inexpensively. Operations have been suspended at these mines since 1874, when Messrs. Malcolm and Co. had two furnaces in blast, after which it passed to the Ducal Iron Company. Some years since the Seend ore was in request in South Staffordshire, and at that time bore a carriage of 7*s.* per ton.

Iron ore of a similar character to that occurring at Westbury in Wiltshire is found in Dorsetshire, at Abbotsbury.* The deposit is described as being "in the upper part of the coral rag, containing oolitic grains of oxide of iron imbedded in a calcareous base and forming an iron ore," of which the following is an analysis by G. D. Livering, Esq., of St. John's College, Cambridge. A portion was taken at random, pounded up, and a part of the powder analysed, so as to give as near the average as possible:—

Sesquioxide of iron	43·97
Silica	42·60
Magnesia	1·40
Lime	trace
Common salt	,,
Water	11·88
Total	99·85

This is equivalent to about 34 or 35 per cent. of iron in the roasted state. At Redlake, a little beyond the village, the ore is of a deep rusty red colour, forming incoherent and heavy masses. About half a mile to the west, on the road to Gorwell, there are bands containing a larger proportion of metallic iron. In the former place it exists to a considerable extent, but in the latter it is less abundant.

Other parts of the coral rag in the neighbourhood of Weymouth are more or less ferruginous, as may be seen in the rusty-looking

* Damons' "Handbook of the Geology of Weymouth and the Island of Portland," 1860, p. 48.

cliff near Sandsfoot Castle, but nowhere is it so rich in iron as at Abbotsbury. At some period these beds may probably be turned to account, either by the erection of furnaces on the spot, or by the conveyance of the raw materials to existing furnaces elsewhere.

Production of Ironstone.—Attention was first directed to these deposits about the year 1855; in 1856 Wiltshire produced 15,000 tons of brown hematite, 5,000 tons being raised at Westbury, and 10,000 tons at Seend, and in the following year this was increased to 15,500 tons.

The following table gives the returns of production since the year 1858, the ore raised at Westbury being smelted at the iron-works of the Westbury Iron Company; the ore at Seend being also smelted on the spot:—

Year.	Westbury.	Seend.	Heywood.	Total.
	Tons.	Tons.	Tons.	Tons.
1858	5,719	4,103	...	9,822
1859	16,947	1,381	10,665	28,993
1860	40,112	32,000	4,088	76,200
1861	37,529	15,000	3,250	55,779
1862	47,900	...	...	47,900
1863	72,612	...	...	72,612
1864	79,918	...	...	79,918
1865	77,291	...	...	77,291
1866	75,645	...	...	75,645
1867	82,586	...	...	82,586
1868	75,084	...	...	75,084
1869	104,795	...	...	104,795
1870	101,423	...	...	101,423
1871	109,151	50,743	...	159,894
1872	95,117	1,000	...	96,117
1873	105,929	34,200	...	140,139
1874	86,120	500	...	86,620
1875	87,152	...	...	87,152
1876	83,957	...	...	83,957
1877	79,176	...	...	79,176
1878	84,756	...	...	84,756
1879	47,623	...	...	47,623
1880	67,500	...	...	67,500

The average value of the Westbury ore may be taken at about 4*s.* per ton, the ore raised at Westbury being smelted at the iron-works of the same name. A glance at the above table will show that Westbury has been the only locality in Wiltshire in which iron ore has been raised since the year 1874.

Analysis of the ore.—The ore raised and smelted at the

Westbury Ironworks is of two varieties, known locally as "brown" and "green" iron ore; the general appearance of the ore is of a dark ochreous character, which, when freshly broken, yields a greenish tinge. The following will show the constituents of each variety, the first-named yielding 41·99 per cent. and the latter 38 per cent. of metallic iron:—

Constituents.	Brown Ore.	Green Ore.
Metallic iron	41·99	...
Oxygen	17·94	...
Silica	18·99	14·720
Alumina	2·79	5·462
Carbonate of lime	3·29	1·327
Magnesia	0·54	trace
Combined water	13·70	...
Protoxide of iron	...	47·250
Peroxide of iron	...	1·325
Carbonic acid	...	29·237
Sulphuric acid	...	0·105
Phosphoric acid	...	trace
Organic matter	...	0·365
Loss	0·73	0·209
	99·97	100·000

The ore worked at Seend, near Devizes, and, as previously stated occurring in the Lower Greensand, has been examined by Mr. Edward Riley, F.C.S., who has determined its composition as follows; side by side appears for comparison an analysis of the iron ore raised from the Northampton sands of the Great Oolite, near Wellingborough, examined by Mr. John Spiller, formerly of the Royal School of Mines:—

Constituents.	Seend Ore.	Wellingborough Ore.
Peroxide of iron	64·61	52·86
Alumina	3·85	7·39
Protoxide of iron	...	0·51
Lime	0·64	7·46
Magnesia	0·20	0·68
Phosphoric acid	0·64	1·26
Carbonic acid	...	4·92
Silica	18·02	13·16
Sulphur	...	0·03
Water	11·85	11·37
	99·81	99·64

The amount of metallic iron contained in the Seend ore is equivalent to 45·22 per cent., that contained in the Wellingborough ore amounting to 37 per cent.

Oxfordshire Iron Ore Deposits.—The "Marlstone," or Middle Lias is the chief repository of the ferruginous ores in this county. The principal localities in which the ore has been wrought, being Fawler, Charlbury, Aynho, Steeple Ashton, Adderbury, and in the neighbourhood of Banbury and Woodstock. As far back as the year 1860 Professor Hull read an interesting paper on the Blenheim iron ore before the meeting of the British Association, in which he remarked "the existence of highly ferruginous beds in the direction of Banbury and Deddington, which had been known for some years, and had to a small extent been quarried and smelted; these are of two varieties, a siliceous ore occurring at the top of the sands which form the lower zone of the Great Oolite, and a calcareous ore forming the upper rock bed of the Marlstone or Middle Lias." During the progress of the geological survey in the neighbourhood of Woodstock, the existence of this latter ore was ascertained in several places, but in particular along the valley of the Cherwell, west of Charlbury; Mr. Hull subsequently gives the following details concerning its nature and stratigraphical position. The Blenheim ore is identical in geological position, and almost in its nature, with the Cleveland ore of Yorkshire. It forms the rock bed at the top of the Marlstone, which, in Gloucestershire and elsewhere produces the tabulated promontories, which jut out from the flanks of the Oolite escarpment. At Fawler it rests upon soft sands, composing the lower division of the Marlstone, and is surmounted by the clay of the Upper Lias. It varies in thickness from 10 to 15 feet of a nearly uniform composition throughout, except where there occurs bands of fossils, with an excess of carbonate of lime. The shells are marlstone species, as "Rhynconella tetrahedra," "Terebratula punctata," &c. At the outcrop the rock presents a rich ferruginous aspect, but when reached at positions where it has been protected from atmospheric influences its colour is deep olive green, and the gradual change may be observed in blocks newly split. In its latter state it appears to be oolitic under the magnifying glass. The character of the iron before oxidation is probably that of carbonate and silicate of iron, the latter imparting the green tinge; when exposed it passes into a hydrated peroxide or

iron. The following gives the order of occurrence of the strata near Fawler, where the Marlstone rock bed gives a thickness of 8 feet:—

Great Oolite, White Shelly Oolite.
Inferior Oolite, Coarse Rubbly Oolite (6 feet thick).
Upper Lias, Grey shales and clay (5 feet thick).
Marlstone Rock Bed, Iron ore (8 feet thick).
Marlstone Sands, Fine sands with balls of concretionary iron ore (15 feet).

The outcrop of the rock may be traced along the valley of the Cherwell at Fawler, on the estate of the Duke of Marlborough. The Marlstone rock bed as seen in the cuttings of the railway between Fawler and Charlbury exhibits in section a thickness of nearly 10 feet.

Recently a considerable tract extending over 500 acres is said to have been acquired by the Ducal Coal and Iron Company, in the neighbourhood of Charlbury, to work the iron ore deposits known as the "Fawler Mines;" it has been contemplated to erect blast furnaces to smelt these ores in admixture with other ores known to exist in the Mendips in Somersetshire, the ore being described as a siliceous hematite containing from 42 to 47 per cent. of metallic iron, and from 20 to 25 per cent. of silica. Already the ores raised from the Fawler and Mendip deposits have been smelted in South Staffordshire at the Hange furnaces of Messrs. Round Brothers at Tipton, in the proportion of three tons of Fawler ore to one ton of Mendip ore, the pig iron produced being of good quality.

The ironstone at Adderbury lies beneath the soil at depths varying from 6 to 8 inches to depths of as many feet. The beds of stone themselves varying from 2 to 10, and in some localities to 12 feet in thickness, and is in some places so compact that the pick which is ordinarily employed is laid aside and blasting resorted to, the deposits assuming the character of a solid rock. The cost of production is moderate, the stone being loaded into trucks at the mine at from 3*s.* 6*d.* to 4*s.* 6*d.* per ton of 2,400 lbs.; the ore is said to be comparatively free from impurities, and is chiefly sent into South Staffordshire, where it is used as a mixture in making forge iron of the best quality. These ores were first wrought about the year 1859; the details of production appear as follows:—

Year.	Fawler.	Adderbury.	Total.
	Tons.	Tons.	Tons.
1859	2,000	3,410	6,030*
1860	4,583	1,250	5,833
1861	5,600	...	5,600
1862	2,244	...	2,244
1863	4,803	...	4,803
1864	6,666	...	6,666
1865	2,557	...	2,557
1866	1,552	...	1,552
1869	...	10,167	10,167
1870	...	38,442	38,803†
1871	...	26,230	28,330‡
1872	...	56,536	63,536§
1873	...	49,962	49,962
1874	...	38,608	38,608
1875	...	34,568	34,568
1876	...	26,140	26,140
1877	...	14,661	14,661
1878	...	6,240	6,240
1879	...	1,233	1,233
1880	...	8,360	8,360

At Steeple Ashton the ore deposits also occur in the Marlstone, an upper bed having a thickness of 14 feet and a lower bed of 12 feet thick, reached by a shaft some 30 yards from the surface, said to be in the Oxford clay. The mines are situated about 6 miles north-east of Woodstock, but of late years the deposits have not been wrought.

Analyses of the Ores.—The Fawler ore very much resembles the yellowish-brown variety raised in Northamptonshire from the Marlstone between the Upper and Lower Lias. In the following analysis from a sample consisting of several specimens the results below appear, and side by side an analysis of the Northampton variety, yielding 39·34 per cent. of metallic iron compared with 31·94 per cent. the yield of the Fawler ore, which, by calcination, is increased to 41 per cent. The last-named analysis is by Mr. Charles Tookey, and was made in Dr. Percy's laboratory, who remarks, as regards the Fawler ore, that "the phosphoric acid is only present in a small quantity as compared with specimens of the Northamptonshire ores which have been examined in this

* Including 620 tons raised at Steeple Ashton.
† Including 361 tons raised at King's Sutton.
‡ Including 2,100 tons raised at King's Sutton.
§ Including 7,000 tons raised at King's Sutton.

laboratory; the absence of this ingredient is an important consideration to the iron smelter":—

Constituents.	Fawler.	Northampton.
Sesquioxide of iron . . .	44·67	56·20
Protoxide of iron . . .	0·86	trace
Protoxide of manganese . .	0·44	0·20
Alumina	7·85	2·43
Carbonate of lime . . .	9·29	0·49
Carbonate of magnesia . .	0·66	0·17
Silica	0·48	...
Carbonic acid	6·11	...
Bisulphide of iron . . .	trace	...
Water hygroscopic . .	16·31	1·16
Water combined . . .		9·74
Phosphoric acid . . .	0·55	0·84
Insoluble residue . . .	13·10	29·07
	100·32	100·30

The insoluble residue of the Fawler ore consisted of silica and alumina, with a trace of lime; that of the Northampton ore from the neighbourhood of Heyford, near Weedon, containing in the residue quartz, soluble silica, and a little mica. Other analyses of ore from the neighbourhood of Fawler, on the Duke of Marlborough estate, examined and reported upon by Dr. Percy, gives the following percentage of metallic iron:—*

Samples.	Metallic Iron.	Samples.	Metallic Iron.
No. 1	38·65	No. 6	36·94
,, 2	35·46	,, 7	31·40
,, 3	37·14	,, 8	22·86
,, 4	34·42	,, 9	13·06
,, 5	32·52		

It is remarked of the two last samples that they contained fossils and a sensible (visible) amount of carbonate of lime.

The Fawler ore already referred to in connection with the Ducal Coal and Iron Company, and operated upon by Messrs. Round, Brothers, gave the following results on analysis by Mr. E. W. T. Jones, public analyst for the county of Stafford. The sample was taken from the heap and examined in the dry state. The sample for the second analysis was obtained from the heading of the underground workings:—

* "Geology of the Country around Woodstock," by Professor Hull, F.R.S., p. 11.

RESULTS TABULATED.

Constituents.	First.	Second.
Protoxide of iron	0·58	1·04
Peroxide of iron	36·50	46·93
Manganous oxide	0·66	0·51
Alumina	7·53	7·86
Silica	10·49	10·55
Lime	19·26	11·79
Magnesia	1·29	1·12
Phosphoric acid	0·71	0·66
Sulphuric acid	0·05	trace
Carbonic acid	14·00	8·55
Pyrites	trace	...
Combined water	9·60	10·15
Loss, &c.	...	0·84
	100·67	100·00
Metallic iron	26·00	33·66
	*0·31	*0·29

The ironstone raised at Adderbury is calcareous in character, the best varieties yielding between 36 and 37 per cent. of metallic iron, while the average throughout may be taken as between 28 and 32 per cent.; the amount of lime varies from 15·50 to 51·00 per cent., and on this account the stone is advantageously used with other ores, producing a very fair quality of pig iron. The constituents of the several varieties appear in the annexed analyses :—

RESULTS TABULATED.†

Constituents.	1.	2.	3.
Sesquioxide of iron	49·50	53·00	29·50
Alumina	12·50	9·50	7·80
Carbonate of lime	19·50	15·50	51·00
Water of hydration, carbonic acid	9·22	13·51	7·91
Silica	9·28	8·49	3·79
Phosphoric acid	trace	trace	trace
Magnesia	trace	trace	trace
Manganese	trace	trace	trace
	100·00	100·00	100·00
Metallic iron (average 31⅝) .	35%	37¾%	22 %
Average	36⅜ % .		...

* Phosphorus.

† Favoured by S. J. Bates, Esq., Birmingham.

Buckinghamshire Iron Ore Deposits.—In the beds of the Lower Greensand in the neighbourhood of Leighton Buzzard, and at Linslade ironstone occurs; in the last-named locality it appears in nodules disseminated through a thickness of about 50 or 60 feet of brown sand. In no instance in the above localities does the ironstone appear in a continuous bed, the nodules are large and massive, of a brown ochreous character, often hollow and found to contain loose white sand. In the year 1857 the pits produced 2,500 tons of ironstone, since which period all operations have been suspended.

Hampshire and Isle of Wight Iron Ore Deposits.—Near the south-western extremity of the Hampshire coast, in the Bagshot beds, occurring near Christchurch, at Hengistbury Head, iron ore was formerly obtained in considerable quantity by the Hengistbury Mining Company. The Bagshot beds occur in the following order:—uppermost, a superficial flint gravel, succeeded by greenish clayey sands, containing four courses of nodular ironstone, the lowest division consisting of dark carbonaceous clay. The ironstone was wrought by cutting back the face of the cliff, the nodules thus obtained varying in size from 5 to 8 feet in length. On the south and east side of the headland, numbers of these massive nodules repose on the beach, mingled with the sands and gravels detached from the cliff, and forming to some extent a natural breakwater against the inroads of the sea, by which the base of the cliff is washed at high water.

In the Isle of Wight, on the shore, at the foot of the cliffs between Yarmouth and Hempstead Ledge, on the north-western coast, argillaceous ore was formerly collected in some quantities and conveyed to the iron works in South Wales. In the table following appear the quantities of ore raised in each locality since the year 1856:—

Year.	Hengistbury Head.	Isle of Wight.	Total.
	Tons.	Tons.	Tons.
1856	13,000	...	13,000
1857	7,000	...	7,000
1858	6,000	934	6,934
1859	6,000	1,803	7,803
1860	5,000	1,119	6,119
1861	3,500	507	4,007
1862	2,800	676	3,476
1863	1,400	...	1,400
1864	4,400	700	5,100
1865	3,000	525	3,525

Since the year 1865 there appears to have been a cessation of mining operations in these districts, the cost of carriage of the ore not enabling the mines to compete with districts more favourably situated, from which a class of ore was obtained giving a higher percentage of metallic iron and at a less cost.

Pig Iron Manufacture.—This industry was commenced in Wiltshire by the Messrs. Greenwood & Co., in the year 1857, when the iron works at Westbury, conveniently situated near the railway station, were projected and put in operation by the above-named firm. In the year 1858 the first furnace was put in blast. The yield for the year 1858 is not separately stated, being included in the production of the Pennywell Road furnaces of the Messrs. Langford & Co. of the adjoining county of Somerset, amounting to 2,040 tons of pig iron. It may therefore be assumed that the production of the Westbury furnace exceeded 1,000 tons, there being at this period but one furnace in blast in each county. In the year 1859 the Messrs. Sarl & Co. commenced the erection of two blast furnaces at Seend, and in the following year they were put in blast. At this period the joint production of the works at Westbury and Seend amounted to 21,785 tons, the make of four furnaces giving an average make of 5,469 tons per furnace. In the year 1861 the Seend Works were out of blast, while those of the Westbury Company were but partially employed, there being but one furnace in blast for a period of eight months; at this time and in subsequent years the production of the Wiltshire furnaces is included with those of Somersetshire. The "Mining Journal" gives the following account of the Seend Works at this period:—

"The Seend Iron Works are situated close to the Seend Station, Great Western Railway, being connected thereto by a siding which connects the pig bank of the furnaces with the main line, and the works are built at the foot of a hill which covers the little rural village of Seend. There are three blast furnaces capable of making 300 tons of pig iron per week. The mine is lifted to the top of the furnace by an ordinary but well-constructed hydraulic apparatus, warm water being supplied for the gravitating purposes of the machine from the exhausted condensing water of the blast engine, without heating cost, which precludes the possibility of hindrance from freezing during the winter months. The furnaces are substantially built, and hot blast is used. The

blast engine is 120 horse-power, substantially erected, working with beam and fly-wheel, and slide valves, with an eccentric cam, being a condenser working the steam at a pressure of 14 lbs., three boilers of the ordinary size being used to generate the steam. The make of iron in these works at the time the above was written was about 250 tons per week, and the quality of the No. 1 iron was very fine, breaking strong, and exhibiting a large crystalline fracture."

The above account by a South Staffordshire ironmaster further states that the furnaces were projected and erected under the superintendence of Mr. Fred. Vernon Smith, the then manager.

In giving the yield of the furnaces of Wilts and Somerset, it only remains to add that the Westbury Company put up a third furnace in the year 1862, and a fourth in the year 1865. The works at Seend appear to have been in abeyance for some years after 1861; later a change of ownership took place, and in the year 1870 the works came into the hands of the Messrs. W. and S. S. Malcolm & Co. renewing the manufacture of pig iron with one furnace in blast, the number being subsequently increased to two. Again in the year 1874 a change of ownership takes place, the Ducal Iron and Coal Company appearing as owners, but who never appear to have put any furnaces in blast.

In the following *resumé* the number of furnaces appear in each district, with the total yield of pig iron in the three counties named :—

Year.	Wiltshire.		Gloucester.		Somerset.		Total Pig Iron.
	Built.	In Blast.	Built.	In Blast.	Built.	In Blast.	
	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.	Tons.
1861	4	2	9	3	2	1	40,493
1862	5	2	9	5	2	0	51,968
1863	5	3	9	6	2	1	64,001
1864	5	3	9	6	2	1	65,312
1865	3	3	9	6	2	1	65,471
1866	3	3	10	6	2	1	59,817
1867	4	3	10	6	2	1	71,186
1868	4	3	10	6	2	1	75,847
1869	4	3	10	6	2	1	81,306
1870	5	4	10	7	2	1	93,601
1871	7	5	9	7	2	1	99,997

In the last-named year the average make per furnace gives 7,692 tons, compared with 5,469 tons in the year 1860. Since

the year 1872, when the consumption of coal became one of considerable interest in the question of the manufacture of iron, returns of the quantities of coal used in pig iron manufacture has been published in the "Mineral Statistics." Following the production of pig iron in Wiltshire, the annexed figures may be generally regarded as a close approximation to the make of the furnaces in each year since that date :—

Year.	Furnaces.		Pig Iron.
	Built.	In Blast.	
	Nos.	Nos.	Tons.
1872	7	5	44,255
1873	7	5	42,844
1874	7	3	26,605
1875	7	2	26,388
1876	7	2	25,718
1877	7	2	24,988
1878	7	2	26,751
1879	7	2	25,000
1880	4	1½	22,350

An examination of the table above shows the increased production of the furnaces; thus, in the year 1872, the average yield was 8,851 tons per annum, compared with 13,194 tons in the year 1875, and 13,375 tons in the year 1878.

The iron ore raised in Wiltshire is smelted in the ironworks of the district, railway communication with moderate freights giving ample means for bringing the necessary materials, coal, and limestone to the works.

The subjoined abstract gives approximately the make of pig iron, and of coal and ore employed in the Wiltshire works since the year 1872 :—

Year.	Pig Iron.	Coal Used.	Iron Ore Used.
	Tons.	Tons.	Tons.
1872	44,255	127,255	...
1873	42,844	119,793	140,139
1874	26,605	74,238	86,126
1875	26,388	79,575	87,152
1876	25,718	60,652	84,162
1877	24,988	61,361	82,966
1878	26,751	59,771	84,756
1879	25,000	58,000	83,000
1880	22,350	50,500	67,500

In the above table ample data is afforded to determine the proportion of materials employed, which may be assumed to vary from 64 to 65 cwts. of ore to each ton of pig iron made, the average yield of the ore from analysis giving 38 to 41 per cent. of metallic iron. This proportion is fully sustained in each successive year, while in the year 1878 a more favourable condition appears, the average of ore not exceeding 63 cwts. to each ton of pig iron made. The quantity of coal employed in like manner in the production of each ton of pig iron points to economy; for example, taking the figures for the year 1872, an average of 57½ cwts. of coal appears for each ton of pig iron made; advancing to the year 1880, the average appearing in the above returns does not exceed 45 cwts. The Westbury Iron Company in addition to their resources of ore in Wiltshire, possess their own colliery at Nettlebridge in the adjoining county of Somerset, where the coal is coked and conveyed to the works at Westbury, and subsequently employed in the smelting of the ores.

Hampshire Charcoal Pig Iron.—About the year 1868 the Messrs. Harrison, Ainslie, & Co., erected a small furnace at Warsash, near Titchfield in the above-named shire for the manufacture of pig iron with charcoal; this furnace was put in blast in the year 1869, and has since continued, with occasional intervals, to make charcoal pig iron according to the supply of charcoal obtainable from time to time in the immediate neighbourhood and in the south of England. The same firm possess other furnaces of a similar construction at Bonawe in Argyleshire, at Newland, near Ulverstone, and Backbarrow, near Haverthwaite, both in Lancashire, and a fifth at Duddon in Cumberland.

A noticeable feature connected with the Warsash furnace is that suitable mechanical arrangements were at an early period successfully introduced, by which the gases escaping from the top of the furnace were utilised as a source of power and made available for raising steam. The ore smelted at these works is brought from Lancashire, a rich red hematite containing from 64 to 66 per cent. of metallic iron; the iron here made enjoys a high reputation, always secures a ready market, and from its superior quality and strength, as well as toughness, compares favourably with the best charcoal irons of Sweden, Norway, and Russia. The quantity annually produced of charcoal pig iron is not considerable in these works, nor is it separately distinguished, being

included with the returns of the other furnaces of the same firm in Lancashire previously referred to.

There is no exact information available showing the quantity of charcoal necessary for the production of one ton of charcoal pig iron ; from inquiries, however, made on the subject of gentlemen conversant with the manufacture, it may be generally stated that the quantity varies from about 46 to 50 cwts. to each ton of iron made.

CHAPTER XIX.

DEVONSHIRE IRON INDUSTRIES.

Iron Ore Deposits—Early account of Magnetic Ores wrought at Haytor—Deposits at Hennock, Buckfastleigh, North Molton, Smallacombe, Torbay (Paint ore) and Exmoor—Analyses, Production and Distribution of Ores.

Iron Ore Deposits.—Ferruginous deposits are more or less abundantly diffused through the formations of every geological age, the richest varieties being found in the older rocks. In this country the most important deposits of red hematite are found in the hollows of the carboniferous limestone in Lancashire, Cumberland and other places, yielding from 60 to 66 per cent. of metallic iron. The other principal sources of supply being the argillaceous carbonates obtained from the ironstone measures of our coal-fields, which with the varieties obtained from the Liassic and Oolitic strata, furnishes by far the greatest proportion of the ironstone smelted in the blast furnaces of Great Britain.

Spathic ores occur in a few localities in this country, which have been already named, and in a few districts in Cornwall and Devonshire; this latter county, though possessing deposits of iron ore of a good quality, does not produce ore in any considerable quantity compared with other districts; still it commends itself to the attention of the ironmaster, occasioning demand when the iron trade is active.

At an early period iron ore (magnetic oxide,) was wrought at Haytor, near Ilsington. Nearly half a century since, Mr. J. T. Kingston, of Ilsington, Devon, published a very interesting account of this deposit in the "Philosophical Magazine." At that time the lode, as far as explored, exhibited much regularity, and is thus described: "The lode occurs in the clay schist, and the direction of its strata is nearly north-west and south-east, underlying to the north-east at an angle of 22° or 23° only for the first few feet from the surface, but below this the

dip is very regular at an angle of 45°, the lode having a width of 28 feet, of which 16 feet was iron ore." From some experiments made, it appears this ore when smelted yielded iron of a tough and superior description, and was at that time used in admixture with the argillaceous ironstone of the coal measures of South Wales. The Haytor ore at the period referred to was favourably regarded for the manufacture of steel; the average yield of the ore being about 50 per cent. of metallic iron, as determined at that period.

Recent analyses of magnetic oxide of iron made in Dr. Percy's laboratory by Mr. Edward Riley, show the following constituents; the ore is presumably that raised at Haytor, the precise locality of the sample examined not being stated. It is thus described: "Magnetic oxide of iron, Dartmoor, Devonshire. It was compact, black, sub-metallic in lustre, uneven and granular on fracture, and gave a black streak. There was disseminated through the ore a pale green mineral, which remained in the insoluble residue obtained by digestion with hydrochloric acid. Traces of bismuth, tin, and copper were detected in a solution of 900 grains of the ore":—

RESULTS TABULATED.

Sesquioxide of iron	62·20
Protoxide of iron	16·20
Protoxide of manganese	0·14
Alumina	2·28
Lime	2·34
Magnesia	0·37
Silica	0·24
Phosphoric acid	0·10
Bisulphide of iron	0·07
Water { hygroscopic	0·28
Water { combined	0·34
Ignited insoluble residue	16·26
Total	100·82

IGNITED INSOLUBLE RESIDUE.

Silica	9·42
Alumina	1·53
Protoxide of iron	1·12
Lime	3·18
Magnesia	1·45
Potash and Soda	0·10
Total	16·80
Metallic iron	57·01

Haytor has produced iron ore in the quantities given in each of the years named:—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1858	3,000	1,420	1872	3,000	1,800
1859	1,293	612	1873	600	450
1861	68	27	1874	1,669	1,500
1862	1,356	542	1875	530	159
1865	2,176	730	1876	1,781	891
1866	60	20	1877	2,611	1,305
1868	1,127	338	1878	724	362
1869	505	151	1879	150	75
1871	200	150	1880	3,395	2,121

At Smallacombe, near Ilsington, in the clay slate or killas, which is traversed by masses of greenstone (dolerite,) highly ferruginous and much decomposed near the surface, ores of iron of two varieties occur—the one brown hematite or limonite, the other magnetite; they are thus described * as they occur at Smallacombe: "The limonite occurs in nodules forming irregular beds in a thick mass of variegated sands and clays, the innumerable layers of which slope gently a few degrees only from the horizontal to the south-east. The magnetite forms three or four beds of variable thickness, occurring in a thick mass of greenstone, which cuts the killas under and west of the beds of limonite. The general dip of the greenstone and its enclosed beds seems to be about 30° from the horizontal and their 'strike' nearly north. The brown iron ore beds have a strike considerably west of north, so that the two series of deposits come together near the north of the estate. The upper part of the greenstone, with its enclosed magnetite, is much decomposed, in fact it is worked for umber; and at a few fathoms below the surface large quantities of garnet rock and crystallised garnets, together with tolerably pure hornblende, have been met with."

At Smallacombe the beds of hematite are wrought in open quarry workings, from which an adit has been driven obliquely through them, westward and northward, for a distance of 90 fathoms, with the object of reaching the beds of magnetite at a greater depth under the hill.

* "Note on the Iron Deposit at Smallacombe, in Devonshire," by J. H. Collins, F.G.S., Miners Association Reports, 1872—73 p. 71.

An examination of the iron ore raised at Smallacombe, made by Mr. Child of the Dowlais Ironworks, shows the following constituents. The equivalent of metallic iron contained in the ore amounted to 50·44 per cent. :—

RESULTS TABULATED.

Sesquioxide of iron	41·96
Oxygen	17·98
Iron as carbonate	8·48
Carbonic acid	9·09
Alumina	1·20
Lime	1·70
Silica	10·15
Phosphoric acid	nil.
Sulphur	trace
Magnesia	trace
Moisture	4·83
Combined Water	5·49
Total	100·88

The following are the quantities of iron ore raised and sold from the Smallacombe deposits; ore was raised in years other than those given, but the quantities are not separately distinguished :—

Year.	Tons.	Year.	Tons.
1865	2,176	1871	352
1866	1,870	1872	1,775
1868	73	1873	1,272
1869	507	1874	2,069

Hennock is another locality, near Bovey Tracey and north of Ilsington, where lodes of iron of a micaceous variety occur, varying from 1 to 12 feet in width, bearing east and west, and occurring in a close-grained porphyritic granite, the ore being associated with quartz, schorl, clay and hornblende; a brown iron ore also occurs at Bishopsteignton, in the limestone in irregular masses.

The Hennock deposit has been worked, at intervals, over a distance of nearly 2 miles, and to the depth of from 20 to 30 feet, and is said to have gone down very rich, the ore being of a micaceous character, yielding 55 per cent. of metallic iron; the lode nearly vertical, and about 4 feet wide, being worked by two adits driven on the lode from the bottom of the hill. At

Hennock Mine in 1872 there appear to have been raised and sold 181 tons.

The ore and its value raised at Hennock in each year since 1873 is as follows :—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1873	3,000	2,250	1876	5,712	2,856
1874	4,386	3,125	1877	3,611	1,805
1875	1,215	911	1878	2,769	1,384

The ore is delivered in trucks on the Devon and Somerset Railway, at the Company's siding, at 10*s*. per ton, and delivered in South Wales at 18*s*. per ton.

At the South Devon Mine, near Buckfastleigh, occur lodes of brown hematite, coursing east and west, and yielding ore of good quality, the lodes being embedded in killas and limestone. The ore raised in 1872 and 1873 amounted to 380 tons and 476 tons respectively, and in 1874 to 255 tons, the value per ton being 15*s*., and the yield of metallic iron 55·0 per cent. Several lodes of iron ore have been, from time to time, worked near Brent, in Devon.

At the Florence Mine, North Molton, lodes of hematite are worked by the Florence Mining Company. The lodes dip at an angle of 62°, and vary from 4 feet to 13 feet in thickness, the levels being opened on two separate lodes. Spathose ore also occurs at this mine, but it is not wrought, as purchasers require it calcined. The ore is said to contain from 50 to 55 per cent. of metallic iron, from 10 to 15 per cent. of silica, and free from phosphoric acid and sulphur.

Spathose iron ore has been met with in the Frank Mills Lead Mine, the lead lode passing into white iron ore in depth. A considerable quantity of this spathose ore was raised, and a few small parcels were sold, but recently a large pile of iron ore was to be seen amongst the waste heaps of the mine. Of this pile of spathose ore, a few samples have been taken from time to time, but the cost of transfer from the mine to the shipping port at Teignmouth, prevents its being purchased for use. An analysis of this ore by Dr. Noad, F.R.S., gives the following results :—

RESULTS TABULATED.

Carbonate of iron	68·53
Carbonate of manganese	14·40
Carbonate of lime	6·48
Carbonate of magnesia	7·40
Sulphide of lead 1·80 =	sulphur 0·23
Silica	1·20
Total	99·81
Iron in raw ore	38·26
Iron in roasted ore	54·70

Dr. Noad appends a note to the above in which he says, "As nearly the whole of the small quantity of sulphur which this ore contains will be expelled by roasting, and as it is perfectly free from phosphorus, he considers it to be very valuable for making the higher qualities of iron, especially for steel.

The ore obtained from Frank Mills since 1872 was in the following quantities and values:—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1872	20	13	1877	12	9
1874	70	105	1879	30	15
1875	100	55	1880	190	95

In the neighbouring lead mines, Exmouth and South Exmouth, in Christow, near Exeter, the same change of the lode into spathose iron ore took place. At the latter mine, a few years since, preparations for working the iron ore were made, but after raising some fine samples from the mine the adventure was abandoned.

Brown hematite iron ore is also wrought in Torbay, on the south coast of Devon, within one mile of Brixham, and between Torquay and Brixham. The ore occurs in the Devonian limestone, which is tilted at a considerable angle, and broken asunder near the surface. In the fissures formed by the rupture of the rock, repose deposits of iron ore, a large proportion being a hard brown and massive hematite, including some kidney ore and soft oxide of iron.

The fissures containing the ore has been said to have a direction east and west, but from the fractured state of the rock, it is not easy to determine this. It is said to extend to a distance of 800 yards from the sea coast, where the deposit at the top of the

cliff shows an irregular width of nearly 80 yards, and somewhat less below. Five pits have been sunk nearly to the sea level, and have yielded ore of good quality. There are several workings at Brixham, but they have been in abeyance for some time owing to the depressed condition of the iron trade. The hematite deposits known as the Brixham Mines, including workings at Sharkham Point, Five Acres and Charter, have been worked by Messrs. W. Brown and Sons. Brown hematite has also been wrought at the Upton Mine, near Brixham, by the Upton Company.

The hematite raised at Brixham, of two varieties, submitted to Dr. Odling, F.R.S., for examination, gives the following results, the first yielding 66·57 per cent., and the second, 48·70 per cent. of metallic iron.

RESULTS TABULATED.

Constituents.	First.	Second.
Peroxide of iron	95·10	69·58
Siliceous matter	4·15	14·38
Sulphur	·12	·15
Phosphorus	trace.	·10
Water	·14	14·39
Organic matter	·49	1·40
Total . . .	100·00	100·00

Other analyses of the Brixham hematite give the following results. One by Dr. Noad, F.R.S., includes an examination of the soft ore, and a second of the ore in lumps, the first being in fine (moist) powder, which was carefully dried:—

RESULTS TABULATED.

Constituents.	Ore in Powder.	Ore in Lumps.
Peroxide of iron	63·42	90·00
Oxide of manganese . . .	0·24	0·30
Lime	0·60	0·42
Phosphoric acid	0·28	0·38
Insoluble sand	35·20	8·60
Total . . .	99·74	99·70

The yield of metallic iron in the soft ore was equivalent to 44·56 per cent., and of the ore in lumps, 68 per cent. Dr. Noad adds, in reference to these analyses, that the first is siliceous in character and not particularly rich in iron; while the second

analysis, of ore in lumps, constitutes by far the largest bulk of the sample, to the extent of seven-eighths is rich and valuable, being materially enhanced by the absence of sulphur and the small percentage of phosphoric acid.

Of the iron ore raised at the mines at Brixham, one kind—a brilliant hematite of a soft variety—is prepared and ground in a mill with linseed oil into paint, which is largely employed in coating ironwork, as a preservative against corrosion, and is commercially known as "Torbay paint." The ore used in this preparation has the following constituents :—

RESULTS TABULATED.

Sesquioxide of iron	89·34
Protoxide of manganese	0·33
Alumina	0·33
Lime	0·33
Magnesia	0·20
Phosphoric acid	0·13
Sulphuric acid	trace
Bisulphide of iron	trace
Water combined	8·83
Ignited insoluble residue	1·70
Total	101·19

These paints are used extensively and advantageously for preserving iron from the corroding influence of impure water, and gaseous exhalations, and are employed by water, gas and railway companies, and in several departments of the Government works.

Other analyses of these paint ores made by different chemists for the original proprietor (Mr. Wolston), who developed the deposits, are as follows :—

RESULTS TABULATED.

Constituents.	Johnson and Cock.	Herapath.	Prince.	Prince.
Peroxide of iron	58·0	46·7	87·0	66·5
Silica	9·3	21·0	7·0	4·0
Alumina	12·3	12·0	2·5	2·0
Water	20·0	...	...	...
Lime	...	2·0	1·0	·5
Oxygen	...	18·3	...	27·0
Oxide of manganese	...	trace	2·5	...
Total	99·6	100·0	100·0	100·0

The production of brown hematite from the mines in the districts here referred to, is as follows, the interruptions in the returns, showing that the mines were in some years either inactive or their output included in the returns of other mines.

The value of the ore F.O.B. in the year 1875 was 15*s.* per ton.

PRODUCE OF THE BRIXHAM MINES.

Year.	Tons.	Year.	Tons.
1856	3,700	1866	20,005
1857	2,000	1867	8,762
1858	1,400	1868	10,976
1859	2,220	1869	6,092
1860	2,400	1870	6,100
1861	5,227	1871	8,772
1862	3,550	1872	1,593
1863	7,014	1874	3,466
1864	9,768	1875	907
1865	16,710	1876	1,603

These mines in the year 1880 appear to have produced some 362 tons of soft ore, of the value of £279.

In North Devon and West Somerset, in that hilly tract of country extending from Ilfracombe to near Bridgewater, considerable explorations have been made in the iron ore deposits, which may be said to extend some thirty miles in length by about five miles in width. Within this area at intervals various iron mines have from time to time been opened. Prof. W. W. Smyth, F.R.S., in a paper * on the iron ores of the district here referred to, thus describes the area: "If from Linton, where the lower beds of the range may be examined, the observer travels southward, he will pass over a constantly ascending series of strata, and about Simon's Bath, on Exmoor, will reach the line of irregular lenticular deposits of limestone, which trending from Coombe Martin by Challacombe, through the midst of Exmoor, to Catborough and Treborough, furnishes an indication of the general strike of the district and a supposed parallel to the more massive limestones of Plymouth."

The ores of iron in Exmoor occur both in regular strata and veins, and it is evident from various circumstances that they were

* "Iron Ore of Exmoor," Geological Society's Journal, 1858, p. 105.

known and worked at an early period. The ores occurring in strata have been found on the flank of Hangman's Hill, near Coombe Martin, in the Valley of the Exe, north-east of Simon's Bath, and in the North Forest, Exmoor, in nodules, generally of small size, and often tilted with the shales in which they occur at such considerable angles, as to render their working difficult. An uncommon variety of chocolate or claret-coloured ore, with an unusually high percentage of iron, is seen in the North Forest of Exmoor. The lodes or iron-bearing veins of this district appear to have a direction running east 10° south, inclining at an angle of from 45° to 65° southwards.

The ore of some of the veins has been examined by Mr. Edward Riley: the first, from the Roman Lode, Cornham Farm, exhibiting small crystals of specular iron, but with a structure through the mass resembling sparry iron (carbonate). The second analysis refers to ore occurring in Roger's Lode, some mile distant, and south of Simon's Bath in the Deer Park, consisting of brown or hydrous peroxide of iron, in a state of great purity, as evidenced by the millions of little prismatic crystals of "Gœthite" lining the interior of numerous cavernous hollows, which are interspersed amidst a mass, bearing evidently the general rhombo-hedral structure of sparry iron :—

RESULTS TABULATED.

Constituents	First.	Second.
Peroxide of iron	98·41	71·34
Peroxide of manganese . .	...	16·79
Oxide of manganese	0·29	...
Silica	1·01	1·49
Magnesia	0·16	0·22
Phosphoric acid	0·12	0·33
Alumina	...	1·10
Lime	...	0·13
Moisture	0·13	0·79
Combined water	...	7·98
Oxide of copper	0·04	0·05
Oxides of nickel and cobalt .	...	0·19
Total	100·16	100·41

The workings in Roger's Lode above referred to, prove it to consist in a width averaging probably 9 feet, of a loosely

agglomerated "Gœthite," with much the same character throughout, occasionally intermingled with bands of quartz and fragments of the adjoining slate rock. At Hangley Cleave, on the extreme south of the Moor, a lode of from 15 to 20 feet wide occurs, of botryoidal and cavernous brown ore, intermingled with quartz and slate, and is succeeded, at the depth of a few fathoms only, first by single nuclei and further by masses of a pale coloured and sparry ore.

Ore in some quantity has been raised on the Moor and conveyed to South Wales, but the cost of carriage has operated unfavourably against the development of the deposits on Exmoor.

In North Devon, near Barnstaple, some promising lodes of iron ore were opened out a few years since, at Spreecombe and Bratton Fleming, manganese being also found in the last-named mine. The lodes at Bratton Fleming are situated on the road to Bratton, close to the village, parallel to each other, and three in number. These lodes are also seen in Haxon Lane, some distance north, where they consist of hematite of good quality. At Haxon Lane, already alluded to, these lodes have been laid open by pits; the north-east is about 2 feet wide, the middle lode 4 feet, and the south-west 4½ feet wide. In a field at Haxon, a lode known as "Clegg's Lode," and another as "Shaft Lode," has been proved; the former is found running in a direction north and south, and forms a junction with the latter, which bears north-west and south-east. The lodes are said to produce ore of good quality. The width of Clegg's Lode is about 1 foot, and that of Shaft Lode 4 feet. Again, at Brent, in South Devon, magnetic iron ore occurs near the river Avon, or Aunn, in shallow deposits on a mass of greenstone. Other deposits in lodes appear on Brent Hill, but the explorations here have been carried out on a very limited scale.

The earliest returns bearing on the production of iron ore in Devonshire appear to refer to the end of the last century, when between the years 1796 and 1802 iron ore amounting to 9,293 tons was shipped from the lodes at Coombe Martin to the ironworks at Llanelly, in South Wales.

Production of Iron Mines.—Since the year 1855 the production of the Devonshire iron mines has been as follows; the output of the mines of the adjoining county of Somerset is given side by side:—

Year.	Devonshire.	Somersetshire.
	Tons.	Tons.
1855	1,500	4,840
1856	4,100	14,620
1857	2,000	25,842
1858	4,754	26,041
1859	3,598	29,083
1860	3,836	24,101
1861	5,399	32,763
1862	3,550	31,413
1863	7,014	34,709
1864	11,068	54,925
1865	37,814	37,984
1866	40,671	35,323
1867	10,212	36,874
1868	11,178	32,450
1869	7,104	27,230
1870	10,103	19,739
1871	14,124	32,883
1872	29,361	30,913
1873	31,455	46,532
1874	21,313	41,432
1875	10,594	45,168
1876	9,936	44,299
1877	6,434	51,928
1878	4,493	43,115
1879	592	14,100
1880	12,652	29,318

The value of the Devonshire iron ores about the years 1874 and 1875 was 15*s*. per ton, since that date it has been declining, till in 1879 it was but 10*s*. per ton.

The latest returns show not only increased production but better prices, the latter exceeding 15*s*. per ton. The mines selling ore in 1880, were as follows :—

No.	District or Mine.	Character of Ore.	Quantities.		Value.	
			Tons.	Cwts.	£	s.
1	Bampfylde . .	Brown Hematite .	1,309	4	785	8
2	Frank Mills .	" " . .	190	0	95	0
3	Haytor . . .	Magnetic Oxide .	3,395	0	2,037	0
4	Kelley . .	Brown Hematite .	22	0	66	0
5	Molland . . .	" " . .	1,681	11	1,008	12
6	New Florence .	Red Hematite. .	5,593	0	5,593	0
7	Brixham . .	" " . .	362	0	279	0
8	" . .	" " . .	100	0	75	0
	Total of Devonshire . . .		12,652	15	9,939	0

Distribution of Devonshire Iron Ore.—It appears furnaces were erected some years ago by the Messrs. Sarl and Sons at Bovey Tracey for the reduction of the iron ores of that district; the furnaces, however, were never blown in, and the works have long since been abandoned and dismantled. The ore is exported to South Wales, and some quantities, though inconsiderable, are conveyed to the North of England. In the annexed table will be found the quantities shipped from the respective ports of Devon, together with the quantities carried by the South Devon Railway in each of the following years:—

Year.	Brixham.	Teignmouth.	Dartmouth.	South Devon Railway.
	Tons.	Tons.	Tons.	Tons.
1865	33,814	1,422	...	...
1866	18,867	1,742	1,000	...
1867	8,829	590	250	...
1868	3,563	345	...	...
1870	5,000	145	...	...
1871	11,000	...	672	...
1872	15,305	301	364	...
1873	2,263	703	...	824
1874	2,166	230	...	5,678
1875	1,906	90	...	...
1876	1,603	290	...	2,566
1877	...	255	...	1,725
1878	...	...	...	811
1879	...	...	...	202
1880	...	...	...	3,277

The railway returns for the year 1874 give the respective quantities carried from the several stations of the South Devon Railway:—

RAILWAY DISTRIBUTION.

STATIONS.	TONS.
From Shaugh Siding	905
Kingsbridge Road	320
Newton	857
Bovey	3,535
Buckfastleigh	151
Total	5,768

In the following table will be found the names of the principal localities in Devonshire above referred to, with the situation

of the mines and the amount of metallic iron contained in the ore :—

Mines or District.	Situation.	Character of Ore.	Iron per Cent.
Haytor . .	Ilsington . .	Magnetic . .	57·01
Hennock . .	„ . . .	Micaceous . . .	55·00
Florence . .	North Molton .	Spathose . .	55·00
Frank Mills . .	Christow . .	„ . . .	38·26
Smallacombe .	Ilsington .	Brown Hematite .	50·44
Torbay . . .	Brixham . .	„ „ . .	66·57
„ . . .	„ . .	„ „ . .	48·70
„ . . .	„ . . .	„ „ . .	44·56
„ . . .	„ . .	„ „ . .	63·00
Brixham . . .	„ . . .	Red Hematite . .	62·50
South Devon .	Buckfastleigh .	Micaceous . .	55·00

CHAPTER XX.

CORNWALL IRON INDUSTRIES.

Early references to Iron Ore Deposits—Borlase and Pryce—Restormel Iron Mine, account of—Analyses of Restormel and other Iron Ores raised in Cornwall—The Perran Iron lode—Production and Distribution of Iron Ore—Mines and Localities producing Ore—Distribution of Iron Ore.

Iron Ore Deposits.—This most western county of England has ever been famous for the great richness and variety of her mineral treasures. The ores of tin were wrought at a very early period, and in Cornwall and the adjoining county of Devon this important ore occurs disseminated through its rocks. Copper ore is also abundant, and but few minerals known to the miner are absent. The ores of iron are widely diffused, occurring principally in the form of lodes, and traversing large tracts of country. These deposits, though long known, have been but partially developed.

Borlase, writing about the year 1758, mentions the fact of iron ore being known to exist in many parts of the county, though not at that time worked. Later, in the year 1788, it appears from Pryce that these lodes of iron still remained unwrought.

The iron ore deposits of Cornwall, as above stated, occur principally in lodes; many of these are known to extend for several miles in a direct course. Generally these lodes have a direction a few degrees west of north, underlying about one foot in a fathom, and containing hematite of the red or brown variety, many of these lodes being in fact the cross courses of the respective districts in which they occur.

One of the most important deposits of iron ore in Cornwall is situated near Lostwithiel, in the Manor of Restormel, held under lease from the Duchy of Cornwall, at a royalty of 6*d*. per ton, and a minimum rent of £40 per annum. The sett is nearly a mile and three-quarters in extent from north to south, and is

traversed throughout nearly its entire length by a large and productive lode of hematite ore. The deposit was originally opened out by a Mr. Adam Thompson, and the property was subsequently acquired by the Messrs. John Taylor and Sons, and worked under the name of the Royal Restormel Iron Mine. Clay slate or killas is the rock of the district, dipping to the east; the lode has a direction north and south, dipping one foot in six, and consisting chiefly of iron ore, quartz, and floocan.

The mine has been extensively worked by means of day levels, while the ore wrought is brought out of the mine by the deep adit, over tramways drawn by horses, to the quays at Lostwithiel, where the ore is shipped in barges and carried to the port of Fowey, whence it is trans-shipped to the ironworks of South Wales and elsewhere. A notable feature in the mine is the new winning below the deep adit, recently opened out, and exposing a run of ore ground, estimated to yield 200,000 tons of ore. Here the plan for draining, working the mine, and dressing the ore, is efficient in all respects for working to a depth of 24 fathoms, and even more, below the adit. The engines are placed underground at the adit; one, a pumping engine, 24-inch diameter cylinder; a hauling engine, the cylinder 12 inches diameter; a double skip road has been made, and a 14-inch plunger fixed; a brick stack being carried up through a shaft to the top of the hill to meet the requirements of the engine and boiler houses constructed under ground at the adit.

The drainage of the mine is economically effected—indeed, there is very little water to get rid of; while the plan of working by a series of cross cuts from the main levels which are driven parallel to, and within a short distance of the lode, enables the rapid extension of the main works without interfering with the extraction of the ore. In the southern part of the sett there is a lode worked open-cast, but here little has hitherto been done.

The quality of the ore obtained from Restormel is now in some request for the manufacture of Bessemer pig. It consists principally of a crystallised brown hematite, or Gœthite, occurring in fibrous and mammilated aggregations, and also in long prismatic crystals. In the upper levels crystals of carbonate of iron altered to brown hematite are met with, while the presence of manganese in these ores render them of value, and well adapted to the manufacture of steel and iron. The percentage of metallic iron

averages from 40 to 42 and 45. Recent analyses, however, of samples taken from the 12-fathom level give higher results.

The following are the results of five samples of ore made by Mr. John Pattinson, of Newcastle-upon-Tyne, for the present proprietors, the Restormel Iron Mining Company, Limited :—*

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Peroxide of iron . .	78·57	56·43	77·14	75·43	45·57
,, of manganese .	4·71	22·60	3·15	·38	32·57
Protoxide of ,, .	...	3·46	...	...	4·28
Oxide of Cobalt . .	...	·13	...	...	·21
Alumina	1·00	3·42	·90	1·00	1·60
Lime.	trace	·36	trace	trace	trace
Baryta	·35	2·58	·10	trace	3·77
Magnesia	·12	·12	·12	·19	·38
Silica	6·00	2·83	9·93	13·97	4·13
Sulphur	trace	trace	trace	trace	trace
Phosphoric acid . .	·06	·33	·16	·19	·40
Combined water . .	8·61	7·14	7·65	8·37	6·46
Moisture	·39	·48	·75	·26	·50
	99·81	99·88	99·90	99·79	99·87
Metallic iron . . .	55·00	39·50	54·00	52·80	31·90
Metallic manganese .	2·97	16·95	1·99	·24	23·87

It is remarked that the amount of silica in these samples is less than in others previously examined from higher levels, and that the ore contains manganese in important quantities. The bulk of the ore may not perhaps show such results as the above samples, but they nevertheless indicate the probability of the deeper workings yielding a more valuable ore than was obtained from the shallower levels.

The ore has also been examined by Mr. E. Riley, F.C.S., with the following results :—

TABULATED.

Moisture at 212° Fahr.	0·85
Metallic iron	46·42
Metallic manganese	3·98
Siliceous matter	18·21

Another sample of ore dried at 212° Fahr., giving 51·76 of metallic iron.

* Favoured by the Messrs. John Taylor and Sons, who also furnished the foregoing particulars of the Restormel Mine.

The returns of production of the Restormel Mine of brown hematite since the year 1855 are as follows :—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1855	20,807	1867	1,005
1856	8,229	1868	608
1857	7,077	1869	1,089
1858	12,956	1871	3,954
1859	6,915	1872	7,521
1860	2,980	1873	4,609
1861	5,519	1874	1,087
1862	2,611	1875	3,510
1863	2,294	1876	4,120
1864	8,357	1877	1,056
1865	6,170	1878	344
1866	4,190	1880	1,724

The brown hematite hitherto worked in Cornwall occurs chiefly in a series of great fissures, which cross the centre of the county on a line nearly coincident with the magnetic meridian, from a point a few miles east of Saint Austell on the south, to the estuary of the Camel at Padstow on the north. On the line referred to, proceeding from south to north, hematite has been worked at the Ruby, Knightor, Treverbyn, Coldbriggen, Withiel, and Pawton Mines, and similar ore has been seen at Resugga, Rosevear Moor, Bilberry, Tresible, and other places. Of the mines referred to, the Ruby on the south, and Pawton on the north, have been hitherto the most extensively wrought, and have proved the most productive.

The Pawton Mine is situated about five miles from Padstow, and three from Wadebridge. The lode bears about 18° west of true north, and underlies to the east about 1 foot in a fathom. It occupies a distinct fissure in the killas; varies from about 1 to 30 feet in width, and averages from 6 to 8 feet. As is usually the case, smaller parallel lodes have been observed on either side of the main lode, but these have not been worked upon. The "Killas" * country is brownish-red, rather soft, and readily decomposes when exposed to the air; it dips gently to the north, so that the lode cuts through it nearly at right angles to its general cleavage, which sometimes coincides with its bedding. The mine so far has been but partially developed. The workings

* "Killas," or clay slate.

extend over a length of about 150 fathoms in all, but north of the engine shaft these are mostly inaccessible. In the upper part of the mine the ore is partially red hematite, but most of it is found to occur as brown hematite. In the stopes below the 22-fathom level, the ore consists occasionally of red hematite, intermixed with spathose carbonate. At all depths much of the ore has been of botryoidal form, and generally very free from silica, sulphur, and phosphorus. The workings have been carried down 33 fathoms. A cross course, about two feet wide, bearing nearly east and west, traverses the lode, and heaves it nearly two fathoms to the left, which is also towards the greater angle. Near the cross course the lode is more siliceous than elsewhere, but this adverse influence only extends to a few fathoms north and south of the intersection. The cross course itself consists chiefly of quartz, but near the lode contains some iron ore also.

The ore raised from the Pawton Mine, examined by Mr. J. H. Collins, F.G.S.,* exhibits the annexed results.

The first analysis consists of portions of ore taken from different parts of the lode, from which a fair average sample was selected :—

RESULTS TABULATED.

Peroxide of iron	93·00
Carbonic acid and moisture	2·50
Silica, chiefly (quartz)	3·60
Sulphur	trace
Phosphorus	trace
Alumina and lime	1·10
Total	100·20

Another sample, selected from ore obtained from the stopes below the 22-fathom level, shows the following results :—

RESULTS TABULATED.

Peroxide of iron	65·0
Carbonate of iron	26·1
Silica	4·4
Sulphur	0·2
Phosphorus	trace
Alumina	1·8
Manganese	1·0
Moisture	1·2
Total	99·7

* Mr. Collins has most liberally placed at the author's disposal the foregoing facts, describing the Pawton and other mines.

It is remarked that the walls of the lode are tolerably regular, that they are not coated with either siliceous matter or "capel," the ore being frequently free from silica, even where it is in contact with the killas. In many parts small "horses" * of killas are enclosed in the ore, which nearly resemble the killas of the adjoining country, as might be supposed.

At Knightor, Treverbyn, and Resugga, the boundary line of which extends some 500 fathoms south, where it gains the Ruby Mine, some important hematite deposits have been proved, extending through the above-named mine sett, consisting of a main lode, and another to the east. These lodes produced ore in some quantities previous to the year 1873, since which date very little appears to have been done, although the ore there raised was of good quality.

The hematite iron ore raised at Knightor and Treverbyn, examined by Mr. Edmund G. Tosh, F.C.S., who remarks that these hematites are quite equal in purity and richness to the best of the district, the first sample being an aggregation of small "kidney ore," in every respect excellent, gives the following results :—

Constituents.	East Lode.	West Lode.	New Lode.
Ferric oxide	94·62	83·29	84·85
Manganous oxide	0·11	0·08	trace
Alumina	0·27	0·55	0·50
Lime	0·09	0·14	0·09
Magnesia	0·03	0·08	0·02
Phosphoric acid	0·018	0·025	0·021
Sulphur	trace	0·020	trace
Siliceous matter	3·39	14·46	11·79
Water and carbonic acid	0·69	1·19	2·34
	99·218	99·835	99·611
INSOLUBLE RESIDUE.			
Silica	3·39	13·86	11·08
Alumina	...	0·47	0.49
	3·39	14·33	11.57
Metallic iron	66·23	58·30	59·40

* A "Horse" in a lode, is a mass of rock in the middle of the vein of ore.

Other analyses of the Knightor and Treverbyn hematite, made by Mr. W. Crosby, of Middlesborough, and Mr. J. H. Collins, of Truro, give the following results; both are described as hematite ore, fair average samples being selected from several points in the above mines; the first containing 58·01, and the second 51·20 per cent. of metallic iron:—

RESULTS TABULATED.

Constituents.	W. Crosby.	J. H. Collins.
Peroxide of iron	82·87	73·2
Silica	8·30	14·4
Alumina	4·30	4·9
Lime	1·24	1·6
Oxide of manganese	0·16	0·3
Magnesia	0·75	0·9
Sulphur	trace	trace
Phosphoric acid	0·03	0·4
Moisture and carbonic acid	2·06	3·4
	99·71	99·1

In the following table is given the production of Pawton in Lanivet and other mines above referred to since the year 1860:—

PAWTON.		KNIGHTOR AND RUBY.		LADOCK.*	
Year.	Tons.	Year.	Tons.	Year.	Tons.
1861	14,400	1862	2,000	1860	1,254
1862	9,876	1863	2,000	1862	762
1863	7,618	1864	7,925	1863	2,413
1864	7,848	1865	6,545	1864	1,177
1865	9,626	1866	7,951	1865	121
1873	1,000	1867	1,772	1872	844
1874	4,372	1868	5,937	1873	512
1876	4,625	1870	5,406	1874	250
1878	617	1871	9,154	1875	200
1880	810	1872	3,901		

The Perran great iron lode is another, and the most, important deposit in Cornwall. Nearly fifty years ago it was referred to, in the "Geological Transactions," by Mr. Henwood, who says: "At the eastern extremity of Ligger Bay is a large vein bearing

* The lode at Ladock yields an ore of good quality of hard brown hematite from 10 to 12 feet wide, embedded in a very supporting light brown killas.

south-east, north-west, and dipping south 50°. It contains hematite, specular, and earthy-brown iron ore, quartz, and slate; has many cavities lined with crystals of quartz, and is traversed by many small quartz veins." * Sir Henry de la Beche wrote in 1839: "There can be little doubt that a large supply of good hematite iron ore could be readily obtained from the district" (of Cornwall and Devon) "if the necessary demand existed." †

Many of the iron lodes of Cornwall are known to extend for several miles in a direct line, and the depth to which the ore holds down is quite unknown. In many respects, however, the Perran lode differs from most of the others, especially in direction, size, underlie, and in the nature of its contents. The Cornish iron lodes have usually a direction a few degrees west of north; average perhaps 3 to 4 feet wide; underlie, about 1 foot in a fathom, and contain either red or brown hematite. On the other hand the Perran lode bears about 35° north of west; averages perhaps 30 feet in width for a course of several miles; underlies from 3 to 4 feet in a fathom, and contains in depth large quantities of carbonate of iron, or spathose iron ore.

The lode is seen on the northern coast of Cornwall at Perran Bay, where it attains a width of nearly 100 feet, consisting of two great branches, divided by a horse of killas or clay slate. The most productive part hitherto explored is that extending to Mount and Trebisken, a distance of some four miles from the coast. It has been traced to the neighbourhood of Grampound, but this latter portion of the lode has not been worked. The first workings were commenced by Mr. Samuel Hockaday, the ore being quarried near the cliff at the outcrop, drawn up over an incline and carted to Newquay, a distance of about six miles, where it was shipped to the ironworks of South Wales. Mr. Hockaday, above referred to, also opened the Mount Mine, about a mile and a-half inland on the same lode. From him it passed to the Saint Columb Bank, and when that failed, to the Agra and Mastermans' Bank. Very considerable workings were made on the lode at the Great Retallack and Duchy Peru mines, which is now worked for zinc. From the extent of the excavations it is probable that not much less than 100,000 tons of iron ore have been removed from this part of the lode.

* "Transactions of the Royal Geological Society of Cornwall," vol. v.

† "Geological Report on Cornwall, Devon, and West Somerset," p. 618.

Previous to the year 1865 a contract was entered into between the manager of the Dowlais Iron Company, and Mr. Carter, of Saint Columb, for the supply of 40,000 tons of the ore. The contract was fulfilled, but the difficulties of transport prevented a renewal of the contract, which was much to be regretted, as the ore gave satisfactory results in reduction to the metallic state. About the year 1874 this lode was vigorously worked by the Cornish Consolidated Iron Mines Corporation; the principal workings are at Gravel Hill, the Mount Mine; still farther east the great excavations at Treamble are situated; a branch of the Newquay Railway leading to the quarries. The Great Retallack Mine adjoins to the north and east; here, in working the iron lode, some 60 or 70 tons of silver lead ore were obtained, the ore containing from 15 to 30 ozs. of silver per ton.

At Great Retallack the lode is found to be several fathoms wide; at one point the workings are down a depth of 40 fathoms, where it was found to be rich for iron, with a little blende for the first 25 fathoms, but at a greater depth the blende increased, and for several months upwards of 500 tons per month were raised and sold at a very low price. The next workings on the lode to the east of Great Retallack are those of the Duchy Peru Mine and Deer Park, where extensive excavations mark the position of the Great Perran iron lode. At the Duchy Peru Mine the old workings on the lead and copper lodes were carried to a depth of 50 fathoms on the iron lode, where white spathose iron ore was met with; here the celebrated Peru lode comes in contact with the great iron lode.

Cellular brown hematite also occurs, and has been raised in some quantity on the western boundary of the Duchy sett. The ore here contains several ounces of silver to the ton, but not sufficient to pay for extraction. Much of the ore contains large "Vugs."* Many of these contain a loosely-fitting kernel of white carbonate of iron. The space between the kernel and the enclosed shell is often filled with water, which is quite clear and tasteless.

The "Killas" country about the great lode at the Duchy Peru Mine seems to be much disturbed; south of the lode it is hard,

* "Vug" or "Vugh." In mining, a cavity, a hollow in the rock or lode.

and appears to dip towards it, but next the lode it is soft, and dips with it; and it is stated that the great bunches of ore in the Perran lode appear to occur where it is crossed by the numerous north and south lead lodes of the district.

Recent analyses of the spathose ores raised at the Duchy Peru and Mount Mines, give the following results. The two first analyses are, from fair average samples, of several thousand tons, while that of Mount Mine was from a stone taken promiscuously from a heap, and weighing about 14 lbs. The three analyses were made by Mr. J. H. Collins, of Truro:—

RESULTS TABULATED.

Constituents.	1.	2.
Protoxide of iron	48·00	46·27
Protoxide of manganese	6·80	5·97
Lime	·63	1·37
Magnesia	2·32	1·88
Sulphur	·43	·28
Phosphoric acid	·10	trace
Insoluble	3·60	3·40
Moisture, alumina, and loss	1·52	4·25
Carbonic acid	36·60	36·58
	100·00	100·00

The spathose ore raised at Mount Mine gave the following results on examination:—

RESULTS TABULATED.

Carbonate of iron	79·00
Carbonate of manganese	9·10
Carbonate of lime	4·90
Carbonate of magnesia	5·20
Sulphur	0·20
Phosphorus	trace
Silica moisture, Alumina and loss	2·00
Total	100·40

Beyond Deer Park the outcrop of the lode is seen on Penhallow Moor, where trials only have been made.

Of the iron ore raised from the several workings on the Perran lode the annexed analyses fairly show their composition; the first two from Gravel Hill, by Mr. J. H. Collins; the third and fourth by Mr. John Mitchell, locality not stated:—

Constituents.	Gravel Hill.	Gravel Hill.	Perran Ore.	Perran Ore.
Peroxide of iron	68·30	70·82	91·428	...
Protoxide of iron	...	...	trace	48·625
Oxide of manganese	·11	·98	·174	trace
Lime	...	...	·110	trace
Magnesia	...	...	·129	...
Potash	...	...	·076	...
Soda	...	...	·054	...
Silica	11·41	11·40	1·140	13·750
Alumina	1·34	2·07	...	6·250
Carbonic acid	...	...	...	29·362
Phosphoric acid	1·21	1·84	·072	...
Sulphuric acid	...	1·12	·013	1·255
Water and loss	15·32	11·40	6·804	·758
	97·69	99·63	100·000	100·000

The equivalent of metallic iron in the Gravel Hill ore amounts to 53 per cent., and of the brown and spathose ore of Perran 64 and 38 per cent. respectively, while as regards the last ore it was found to contain 8 ozs. 3 dwts. and 8 grains of silver per ton.

The ore raised at Treamble Mine, of three varieties of fair average samples, show the annexed constituents. The first analysis is by Dr. Noad, the second by Mr. Collins, and the third by the Wigan Coal and Iron Company:—

Constituents.	Brown Hematite.	Kidney Ore.	White Spathose.
Silica	4·20	10·00	1·74
Peroxide of iron	69·10	78·10	...
Peroxide of manganese	14·00	trace	8·13
Protoxide of iron	...	...	51·61
Lime	·80	trace	1·51
Magnesia	...	...	·36
Alumina	...	trace	...
Sulphuric acid	·24	...	·15
Phosphoric acid	...	1·44	trace
Carbonic acid	...	...	35·55
Water	11·60	10·00	...
	99·94	99·54	99·05
Metallic iron	66·23	...	...

The production of the several mines on the Perran lode above referred to are given as follows, and this important deposit can furnish considerable quantities of ore to the ironmaster whenever circumstances may arise causing increased demand:—

DUCHY PERU.		TREBISKEN AND MOUNT.		TREAMBLE.	
Year.	Tons.	Year.	Tons.	Year.	Tons.
1858	2,762	1859	4,338	1859	2,391
1859	1,995	1860	2,641	1860	1,312
1860	4,895	1861	1,860	1864	222
1862	169	1864	2,876	1873	426
1863	3,950	1865	6,193	1874	9,438
1864	2,366	1866	1,234	1875	958
1865	3,539	1871	2,785	1876	426
1866	150	1872	8,293	1880	2,728*
1872	50	1873	4,706		
1873	528	1874	2,545	GREAT RETALLACK.	
1874	2,566	1875	374		
1875	412	1876	517	Year.	Tons.
1876	1,121	1877	283		
1878	17	1880	379	1858	4,017
1880	3,238			1859	6,609

At Gravel Hill 2,505 tons of iron ore were raised in the year 1874, and 494 tons in 1875. Again, in 1876 about the same quantity, increased in 1880 to 2,652 tons.

West of Bodmin, and distant some three miles at Boscarne, occurs a lode partly wrought; this lode has a run of some 750 fathoms, worked to a depth of 20 fathoms, with an average width of 1 fathom. Other lodes, known as the Nantallon lodes, occur south of Boscarne; these are three in number, running with little variation north and south, with a slight underlie. Two of the lodes have a range of nearly 1,750 fathoms, while the third has a range of 2,200 fathoms. The average depth to which these lodes have been worked does not exceed 20 fathoms, while in width one is 3 feet, and the remaining two are each 6 feet or 1 fathom in width. The ore wrought at Nantallon is of the variety known as "fibrous kidney ore," the iron existing in the form of hydrated peroxide.

At Tregorne, to the west of Mulberry Hill, hematite, of an irregular structure and associated with quartz, has been wrought, occurring as anhydrous peroxide, the lode having a range of some 500 fathoms, 30 fathoms in depth, and with an average width of 3 feet. Other lodes occur to the west and south of Bodmin; at Tremoor two lodes, extending some 2,000 yards, 15 fathoms deep, and with an average width of 3 feet; again, at Withiel, Retire,

* Perran Mines, including Treamble and others.

Coldvreath, and Trerank. The Coldvreath lodes have formerly been worked to some extent, their direction extending 800 fathoms north and south, 16 fathoms in depth, and having an average width exceeding 1 fathom. The ore raised at Coldvreath is known as compact hematite, a small portion being distinguished as "kidney ore."

Many other localities in Cornwall are known to yield iron ore of good quality; in the district of Constantine, to the east of Falmouth, a lode of iron ore, wrought in recent years, varying from 6 feet to 6 inches in width, has produced ore in notable quantity. In the district of Saint Columb lodes occur, one worked at the Ruthers Mine. Again, we have those of Indian Queens and Trelivier, near Saint Austell; the former was opened out about the year 1866, and continued in operation nearly ten years.

The ores raised in the neighbourhood of Saint Austell, near Grampound, at the Kernick and Bodennick mines, is a brown hematite, the thickness of the lode at the former varying from 27 to 31 feet, and the latter having an average of 13 feet 6 inches; these have been partially wrought. The ores, examined by Dr. Noad and Dr. Perkins, are described as compact brown hematite, intermixed with spar at the outcrop, but comparatively free from it about 14 feet below; they contain by analysis from 76 to 80 per cent. of peroxide of iron, some oxide of manganese, no sulphur, and a small admixture of phosphoric acid. The following are the results:—

Constituents.	Dr. Noad.	Dr. Noad.	Dr. Perkins.
Peroxide of iron	76·00	79·56	80·20
Oxide of manganese	3·20	1·20	2·01
Lime	1·00	1·20	·14*
Magnesia	...	·53	...
Sulphur	...	...	...
Phosphoric acid	·30	·28	·09
Silicate of alumina	10·00	7·20	15·50†
Water	9·50	10·00	2·06
	100·00	99·97	100·00

The equivalent of metallic iron contained in the peroxide being respectively 53·2 per cent., 55·6 per cent., and 56·17 per cent.

* Lime and alumina. † Silica.

At South Terras, near Grampound Road, a magnetic ore of iron is wrought, giving on examination the following results:—

RESULTS TABULATED.

Magnetic oxide of iron	84·24
Peroxide of iron	3·84
Magnesia	trace
Lime	trace
Phosphoric acid	trace
Sulphur and sulphuric acid	trace
Lead	faint trace
Oxide of magnesia	1·06
Alumina	1·35
Silica of gangue	7·51
Water	2·00
Total	100·00

Production of Iron Ore.—The produce of a few of the more important iron mines has already been given; in the table below appears the total output of the mines of Cornwall in each year since 1855:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1855	24,057	1867	6,426
1856	22,650	1868	8,310
1857	19,359	1869	4,619
1858	55,150	1870	11,214
1859	35,213	1871	21,947
1860	23,953	1872	48,199
1861	26,262	1873	31,455
1862	24,626	1874	45,055
1863	18,975	1875	11,403
1864	34,210	1876	18,390
1865	36,112	1877	4,963
1866	18,683	1878	1,308

In the year 1874, when the Cornish ores were in good demand, the following will show the value per ton:—Gravel Hill, Treamble, and the Duchy Peru, 15*s.* 6*d.*; Pawton, 16*s.*; Ladock, 17*s.*; Coldvreath ore, 17*s.* 6*d.*; and Blackhay, 16*s.* per ton. In the year 1879 the last-named mine was the only one in Cornwall working; it produced but 400 tons, of the value of £240, giving an average value of 12*s.* per ton. In 1880 greater activity appears, the total output amounting to 15,865 tons, of the value of

£9,845, giving an average of 12*s.* per ton. The produce and value of the iron ores raised were as follows in the year 1880:—

No.	District or Mine.	Character of Ore.	Quantities. Tons.	Cwts.	Value. £	s.
1	Blackhay	Brown Hematite	950	0	570	0
2	Duchy Peru	,, ,,	3,238	0	1,942	16
3	Gravel Hill	,, ,,	2,652	0	1,856	8
4	Lanivet	,, ,,	810	0	486	0
5	Restormel	,, ,,	1,724	17	1,120	12
6	Ruthers	Red Hematite	134	10	94	2
7	Mount	Spathose	269	16	134	18
8	Mount	Brown Hematite	110	0	55	0
9	South Terras	,, ,,	3,000	0	1,800	0
10	Retew	,, ,,	248	0	148	16
11	Perran Mines	,, ,,	2,728	0	1,636	16
	Total of Cornwall		15,865	3	9,845	8

The principal iron mines in Cornwall, their situation, with the character of the ore raised, appear in the following table:—

Iron Mines.	Localities.	Character of Ore.
Blackhay	Withiel	Brown Hematite.
Colbiggen	Roche	,, ,,
Coldvreath	St. Austell	,, ,,
Constantine	Constantine	,, ,,
Deer Park	Perran	,, ,,
Duchy Peru	,,	Spathose and Hematite.
Gravel Hill	,,	,, ,,
Granville East Wheal	Camborne	,, ,,
Knightor and Treverbyn	St. Austell	Brown Hematite.
Ladock	Ladock	,, ,,
Lanivet	Lanivet	,, ,,
Mount and Trebiskin	Perran	Spathose and Hematite.
Old Treburgett	St. Teath	,, ,,
Mills, New	Ladock	Brown Hematite.
Pawton	St. Breocks	,, ,,
Restinnis	St. Blazey	,, ,,
Restormel	Lostwithiel	,, ,,
Ruby and Tregurthy	St. Austell	,, ,,
St. Stephens	,,	,, ,,
South Terras	Grampound	,, ,,
Treamble	Perran	Spathose and Hematite.
Trebarvah	,,	Brown Hematite.
Tretoil	Bodmin	,, ,,

Distribution of Ore.—The iron ores of Cornwall, in times of commercial activity, are in good demand for the economical

production of iron, either when used alone or in admixture with poorer ores. These ores find a market in Mid-England and the Northern iron-making districts. The principal shipping ports on the north coast are Padstow, New Quay, Saint Agnes; and on the south coast, Truro, Fowey, and Charlestown. As far as returns are obtainable the table below gives the quantities shipped in each year since 1859 from the ports named :—

PADSTOW.	
Year.	Tons.
1859	8,806
1861	8,209
1864	7,618
1865	9,626
1866	4,350
1867	468
1868	1,256
1869	1,200
1870	933
1871	2,132
1872	6,132
1873	6,486
1874	6,406
1875	2,089
1876	4,605
1877	443
1878	617
1879	75
1880	810

NEW QUAY.	
Year.	Tons.
1865	4,000
1866	1,602
1868	2,164
1879	100
1880	5,860

ST. AGNES.	
Year.	Tons.
1865	4,400
1866	1,974
1871	526
1872	2,234
1873	2,027
1874	118
1875	196

TRURO.	
Year.	Tons.
1865	1,700
1866	2,637
1871	3,500
1872	7,200

CHARLESTOWN.	
Year.	Tons.
1876	1,779
1877	662
1878	225
1879	152

The Cornwall and South Devon Railway has also distributed some of the Cornish iron ore as follows in each of the years given :—

Year.	Tons.	Year.	Tons.
1876	2,566	1878	811
1877	1,725	1879	202

And in the year 1880 some 3,277 tons. The quantities given are comparatively unimportant, but they serve generally to show the depressed condition of the iron industries of Cornwall at the present time. On the other hand, Cornwall, whenever the demand may arise, may probably supplement the resources of our iron-making districts by the development of her ferruginous deposits, and expand an important industry in the interest of that western county.

CHAPTER XXI.

IRON INDUSTRIES OF SCOTLAND.

Iron Ores of the Coal Measures—Clay Bands and Black Bands—Discovery of Black Band Iron Ore by Mushet, in 1801—Analyses and Production of Clay and Black Band and other Iron Ores—Population employed in Iron Mining—Pig Iron Manufacture—Early History, 1750—Charcoal Iron—Carron Works—Smeaton's blowing machinery—Account of Devon Iron Works, 1782—Hot Blast, invention by Neilson, 1829—Extension of Iron Works and their resources—Production of Pig Iron—Works in 1880—Distribution and average prices of Pig Iron—Exports and Home Consumption—Malleable Iron Works—Account of Dalziel Steel Works—Production of Malleable Iron and prices—Coal and Iron Ore used in Pig Iron Manufacture—Iron Shipbuilding.

Ironstone of the Coal-fields and Analyses.—The principal ironstone measures have been already referred to in the several sections given in the coal-fields of Scotland. A brief notice of the black band ironstone, which has so largely contributed to the development of the iron industries of Scotland, will here be interesting. It was originally discovered by Mr. Robert Mushet in the year 1801, at Airdrie, near Glasgow, in Lanarkshire, but it does not appear to have come into general use till about the year 1830. The Possil black bands were discovered in the year 1838, and have an average thickness of 9 inches. Subsequently in the year 1840, black band ironstones were discovered in Ayrshire, giving rise to the important ironworks of Blair and Glengarnock; and some years later it was found extending from Dalry, in Ayrshire to Banton, in Stirlingshire, and more recently at Lugar and Dalmellington, in Ayrshire; at Forth, Lochgelly and Lumphinnans, in Fifeshire; at Borrowstoness and Almond in Stirlingshire, and in other places.

A very important seam of ironstone was discovered a year or two since, 24 inches thick, on the lands of the Carron Iron Company, near Eastgrange, Culross; the same seam was long known and worked to the east of the locality above referred to, and a search was instituted for its discovery. Boring operations were carried on for several months, and at a depth of 140 fathoms the

efforts of the borers were rewarded by cutting this valuable seam. It is related that some years previously similar operations were conducted by the Shotts Iron Company on the same estate, the borings being carried to a depth of 100 fathoms, but not meeting with the seam the company relinquished the lease.

Brown Iron Ore.—Ores of iron occur and are worked in some few localities in various parts of Scotland, but to a very limited extent, due in most cases to the remote districts, the want of cheap carriage to the ironworks, and the necessary fuel for their reduction. In Ayrshire, hitherto, hematite has been worked at Muirkirk and at Whytock; in Haddingtonshire at Garleton, and in Shetland at Sandlodge; also in the northern counties of Aberdeen and Moray, and in Kirkcudbrightshire at Auchencairn. The great bulk of the hematite employed in the blast furnaces of Scotland is imported from the west coast of Lancashire and Cumberland, from Spain and other foreign countries.

The iron ores most generally employed in the furnaces of Scotland are black bands and clay bands, and a certain admixture of brown iron ores previously referred to. Black band ironstone may be described as a compact, dull, earthy mineral, with frequently a schistose or ribbon structure, varying in colour from deep brown to black. Some varieties contain little but carbonate of iron and carbonaceous or bituminous matter, silica, alumina, lime and manganese entering into their constituents in a very minute proportion. The carbonaceous matter contained in these black bands is generally sufficient to effect their calcination without the aid of additional fuel. They are very valuable ores, easily and cheaply calcined in heaps in the open air, the residue yielding from 50 to 70 per cent. of metallic iron.

Mushet's black band is thus constituted, as determined by the analysis of Dr. Colquhoun, who devoted considerable attention to the iron ores of Scotland:—

RESULTS TABULATED.

Carbonic acid	35·17
Protoxide of iron	53·03
Lime	3·33
Magnesia	1·77
Silica	1·40
Alumina	0·63
Peroxide of iron	0·23
Bituminous matter	3·03
Water	1·41
Total	100·00

The amount of metallic iron being equivalent to 40 per cent.

The wide variation in the produce of various measures of black band ironstones appear in the annexed table of analyses:—

TABULATED RESULTS OF SCOTCH BLACK BAND IRONSTONES.

Constituents.	1.	2.	3.	4.	5.	6.
Carbonic acid	32·71	32·61	22·87	33·08	30·74	30·95
Protoxide of iron . . .	47·31	42·02	32·14	41·65	44·19	45·78
Lime	1·79	3·65	2·82	5·76	2·22	1·79
Magnesia	1·73	3·54	1·08	3·52	0·91	1·30
Silica	1·20	4·40	12·40	0·52	2·12	1·60
Alumina	0·80	2·64	7·06	0·96	0·92	1·28
Protoxide of manganese . .	1·67	0·82	1·05	..	1·93	1·12
Bituminous matter . . .	10·40	9·12	18·60	11·16	15·52	7·85
Phosphoric acid . . .	0·59	0·46	0·82	0·84	0·43	0·55
Sulphur	..	..	0·22	0·25	0·22	3·28
Iron combined with sulphur .	..	..	0·19	0·22	0·19	2·87
Water.	1·80	0·74	0·75	2·04	0·61	1·63
Total . . .	100·00	100·00	100·00	100·00	100·00	100·00
Metallic iron	36·80	32·68	25·19	32·62	34·56	38·47
Yield of calcined ore . .	..	..	61·28	58·20	56·41	60·85
Metallic iron in calcined ore .	..	..	41·10	56·04	61·27	63·22
Silica in calcined ore . .	..	..	20·24	0·90	3·76	2·63

Analyses 3 to 6 were made by Mr. John Saint Day, C.E., who in a paper read at the Glasgow meeting of the British Association in the year 1876, entered very fully into the iron and steel industries of Scotland. Other analyses from Mr. Day's paper, may be summarized as follows, showing the amount of metallic iron contained in various black band ironstones, and other results:—

BLACK BAND IRONSTONES.

	1.	2.	3.	Slatey Band.	
Yield of metallic iron .	36·36	32·68	36·80	31·54	31·51
Yield of calcined ore. .	63·60	62·26	60·48	59·64	52·85
Metallic iron in ore .	57·16	52·50	60·85	52·88	59·61
Silica in ore . . .	5·41	7·06	1·98	11·94	3·60

Taking the average yield of metallic iron, the black band ironstones of Scotland do not exceed 35 per cent. These ores, when calcined, yield from 50 to 70 per cent. of metallic iron, the average may be taken as 60 per cent.; those of other districts vary considerably. The next most important measures of black

band in Great Britain are those obtained in the North Staffordshire coal-field; reduced in the furnace without admixture with other ores. Like the Scotch black bands, they make a very good quality of iron, are extensively raised and calcined, and in this state sent into the South Staffordshire districts, for the most part wanting in black band ores.

The argillaceous or clay band ironstones, like the black bands, vary considerably. Numerous analyses are available showing the composition of these ores, the series, however, made by Mr. Day, in his paper previously referred to, are so complete, that they have been selected for illustration: *—

TABULATED RESULTS OF SCOTCH CLAY BAND IRONSTONES.

Constituents.	1.	2.	3.	4.	5.	6.	7.
Protoxide of iron	47·31	39·60	34·98	37·23	32·20	24·90	37·54
Protoxide of manganese	trace	1·52	0·82	1·96	1·64	1·22	3·60
Lime	0·97	1·79	1·66	5·17	5·74	16·55	6·50
Magnesia	0·91	3·96	2·08	4·17	4·08	7·54	0·43
Carbonic acid	30·22	30·31	25·46	32·21	29·60	35·61	28·94
Phosphoric acid	0·49	0·64	0·50	0·45	0·60	1·76	1·92
Sulphur	trace	0·08	0·11	0·28	0·51	0·31	0·27
Iron combined with sulphur	..	0·07	0·10	0·25	0·45	0·27	0·24
Alumina	7·10	7·93	11·66	5·12	6·55	3·27	6·23
Silica	10·12	11·80	17·80	10·44	14·60	6·80	11·20
Bituminous matter	2·32	1·55	4·17	1·75	2·84	0·73	2·03
Water	0·56	0·75	0·66	0·97	1·19	0·52	1·10
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Metallic iron	36·80	30·87	27·30	29·21	25·49	19·63	29·41
Yield of calcined ore	72·16	70·39	72·28	67·80	68·53	64·77	70·94
Metallic iron in ore	51·00	43·84	37·77	43·05	37·19	30·38	41·50
Silica in ore	14·03	16·77	24·62	15·40	21·30	10·50	15·77

The average yield of metallic iron from the argillaceous ores of Scotland may be regarded as about 30 per cent., and when calcined about 70 per cent., compared with the black bands which, as already stated, give an average of 35 per cent. of metallic iron in the raw state and 60 per cent. when calcined.

The hematite obtained at Auchencairn, in Kirkcudbrightshire, is very similar in character to the kidney ore of Whitehaven, in Cumberland, and like another variety known as "small kidney ore," obtained in the same locality, yields a high percentage of metallic iron. Analyses of the two varieties by Mr. Robert Mushet, are as follows :—

* "Iron," 30th September, 1876.

Constituents.	Large Kidney Ore.	Small Kidney Ore.
Peroxide of iron	88.00	98·43
Silica	11·53	1·57
Alumina	0·47	trace
Total . . .	100·00	100·00

The small kidney ore may be regarded as a pure peroxide of iron, yielding 68·91 per cent. of metallic iron; the large kidney ore giving 61·60 per cent.

In one locality at Auchencairn the hematite exhibits two varieties of ore, known as "Black Metal Kidney Ore" and "Red Ore," the former a compact oxide of iron, yielding 55·63 per cent. of metallic iron, the red ore ranging from 44 to 63 per cent., and a mixture of the two varieties giving 51·79 per cent. of metallic iron. The annexed analyses show the composition of both varieties:—

Constituents.	Black Metal.	Black Metal and Red Ore.
Peroxide of iron	79·46	73·98
Silica	14·07	17·45
Alumina	1·36	1·04
Moisture	5·11	4·31
Magnesia	...	3·22
Total . . .	100·00	100·00

A detailed analysis of the variety known as "Red Ore" of Auchencairn gives the following tabulated results:—

ANALYSIS OF "RED ORE."

Peroxide of iron	63·00
Oxide of manganese	0·72
Lime	1·74
Magnesia	1·33
Carbonic acid	2·42
Phosphoric acid	trace
Alumina	4·09
Silica	23·20
Water	3·50
Total	100·00

The equivalent of metallic iron in the above peroxide amounts to 44·10 per cent.

The hematite occurring at Sandlodge, in Shetland, contains upwards of 70 per cent. of metallic iron and a small percentage of copper. Another variety, known as "Gossan," rich in iron, containing 60 per cent., in addition to 3 per cent. of copper; this last variety is extensively used for purifying gas.

Production of Ironstone in Scotland.—The earliest information on this subject begins with the year 1855, when the Keeper of Mining Records for the first time ascertained that the production of all kinds of ironstone, clay band, black band and hematite raised in Scotland amounted to 2,400,000 tons, the production of Great Britain in the same year amounting to 9,953,741 tons; it thus appears that in the year referred to, Scotland produced nearly 25 per cent. of all the ironstone and ore raised in the kingdom. Since the year 1855 the ironstone production of Scotland appears as follows, so far as returns have been received :—

Year.	Tons.	Year.	Tons.
1855	2,400,000	1868	1,250,000
1856	2,201,250	1869	1,950,000
1857	2,500,000	1870	1,980,000
1858	2,312,000	1871	1,975,000
1859	2,225,000	1872	1,978,000
1860	2,150,000	1873	1,986,000
1861	1,975,000	1874	2,119,771
1862	1,500,000	1875	2,452,235
1863	1,500,000	1876	2,552,553
1864	1,950,000	1877	2,621,852
1865	1,470,000	1878	2,443,923
1866	1,587,000	1879	2,458,407
1867	1,264,800	1880	2,659,317

The reports of H.M. Inspectors acting under "The Coal Mines Regulation Act," show that in the year 1874 the production of ironstone in Scotland was 2,119,771 tons, compared with 2,659,317 tons in the year 1880; of this quantity 1,435,647 tons were black band, and 1,223,670 tons clay band. The annexed statement gives the production of each shire in the eastern district of Scotland in the same years as follows; the western district giving 1,418,698 tons and 1,887,274 tons respectively :—

Counties.	1874.	1880.
Eastern Scotland—	Tons.	Tons.
Clackmannan, Perth, Kinross and Sutherland.	7,890	...
Edinburgh	39,661	101,619
Fife	59,272	652
Haddington	8,601	458
Lanark, part of . . .	342,224	510,342
Linlithgow	238,605	148,423
Stirling, part of . . .	4,820	10,549
Total . . .	701,073	772,043
Western Scotland . . .	1,418,698	1,887,274
Total of Scotland .	2,119,771	2,659,317

In the year 1874 the total production of all kinds of iron ore in the United Kingdom amounted to 14,844,936 tons, the estimated value at the place of production being £7,313,146; ten years previously, in the year 1864, the iron ore raised in the United Kingdom amounted to 10,064,890 tons, of the value of £3,367,144, while in the year 1880 the production reached 18,026,049 tons, of the value of £6,585,806.

Since the year 1875 the Inspectors' annual reports give the aggregate production in each of the iron ore producing districts of Scotland. The annexed table shows the yield of each district in Scotland, since the year 1875, of all varieties of ironstone and hematite:—

Counties.	1875.	1876.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Ayrshire . .	853,868	860,648	856,129	930,121	947,636	1,008,253
Dumbartonshire .	231,885	249,637	284,875	257,515	287,810	290,560
Edinburghshire .	49,469	61,262	75,779	57,565	92,891	101,619
Fifeshire . .	36,833	14,274	13,113	19,463	9,827	652
Haddingtonshire .	9,899	6,224	4,340	2,101	550	458
Kinrosshire and Perthshire .	14,264	41,100	31,274	21,559	..	..
Lanarkshire .	747,406	779,263	803,382	635,272	681,231	757,291
Renfrewshire . .	170,106	185,678	180,596	173,529	174,118	223,831
Stirlingshire .	143,165	162,781	172,573	169,104	108,766	128,230
Linlithgowshire .	188,772	186,460	194,322	170,126	155,086	148,423
Sundries, hematite	8,568	5,226	5,469	7,568	492	5,166
Total .	2,454,235	2,552,553	2,621,852	2,443,923	2,458,407	2,664,483

In the three years ending 1880 the separate varieties of ore

raised from the coal and ironstone measures and the hematite deposits of Scotland are separately distinguished, and are as follows:—

Year.	Clay Band.	Black Band.	Hematite.
	Tons.	Tons.	Tons.
1878	1,123,772	1,312,583	7,568
1879	1,135,247	1,322,668	492
1880	1,223,670	1,435,647	5,166

Population employed in Ironstone Mines.—But little information exists on this subject before the year 1873; in that and succeeding years the reports of H.M. Inspectors of Mines give the following as the numbers employed under ground and above ground in the eastern and western Inspection districts of Scotland:—

Year.	Eastern District.		Western District.		Total Persons Employed.	Ironstone Returned.
	Above.	Below.	Above.	Below.		
	Nos.	Nos.	Nos.	Nos.	Nos.	Tons.
1873	640	3,311	1,673	8,029	13,653	1,986,000
1874	827	4,066	1,757	7,898	14,548	2,119,771
1875	788	3,885	1,641	7,313	13,627	2,452,235
1876	871	3,776	1,734	7,364	13,745	2,552,553
1877	826	3,826	1,631	7,002	13,285	2,621,852
1878	702	3,123	1,530	7,179	12,534	2,443,923
1879	648	2,928	1,371	6,704	11,651	2,458,407
1880	652	2,924	1,582	7,133	12,291	2,659,317

These returns show a high state of efficiency, the average work of the miner increasing from 145 tons in 1873 to 185 tons in 1876, and 215 tons in 1880, showing an increase of 48 per cent. in the above period.

Pig Iron Manufacture.—The earliest information bearing on iron smelting in Scotland dates about the year 1750, in which year the first furnace was erected at Bunawe, in Argyleshire, by a Mr. Ford. In this furnace the blast was impelled by water power obtained from the river Awe, the ore employed being hematite brought from Ulverston, in Lancashire, while for fuel charcoal alone was used, with the aid of cold blast. The iron thus manufactured enjoyed then, as now, a high reputation, and for purposes

of conversion into crucible steel is quite as reliable as the best Swedish or Russian brands.

The Bunawe furnace, now known as the Lorne, is still occasionally in operation, the proprietors being Messrs. Harrison, Ainslie & Co., who continue to make charcoal pig iron, according to the supply of charcoal obtainable. Previous to the year 1788 there appears to have been a similar furnace erected at Goatfield, also in Argyleshire, and it is recorded that the yield of the Bunawe and Goatfield furnaces in 1788 amounted to 1,400 tons, or 700 tons each furnace. The charcoal iron manufacture in Scotland followed precisely the same conditions as those prevailing in other parts of the kingdom; with the exhaustion of the woods, the use of coal was gradually introduced.

The Carron Ironworks, situated on the bank of the Carron river, about two miles from Falkirk, were projected and the first furnace put in blast in the year 1760. The site of Carron was selected on account of the abundant water supply, and the immense deposits of coal, ironstone and limestone in the immediate neighbourhood of the village. The name of Dr. John Roebuck is intimately associated with the Carron Works; he was the principal proprietor of the works, and a man of considerable scientific attainments, devoting his energy most thoroughly towards the development of the iron industries of Scotland. The Carron Works were erected by the eminent engineer John Smeaton; it was at these works that the powerful blowing machinery invented by the same engineer was first introduced; the blowing machinery referred to consisted of 4 cylinders, 4 feet 6 inches in diameter, exactly fitted with pistons, and so contrived that the strokes of the pistons being made alternately produced an almost uninterrupted blast. The pumps were worked alternately by means of a powerful water wheel, which had 4 cranks upon the axis, each of which moved the piston of a cylinder, through its stroke of 4 feet 6 inches.

The great advantages secured by Smeaton's invention enabled the ironmaster to consume the hard dense coke in the furnace which the ordinary bellows previously in use was unable to effect; an increased yield of the furnace was the result: previously it had been from 10 to 12 tons per week, now it rose to 40 tons in the same period, and on the average 1,500 tons of pig iron were made per annum. It was in the immediate neighbourhood of

Carron that James Watt, in association with Dr. Roebuck, erected his first steam engine, the patent for which was secured in the year 1769. In that year too the first carronade, the invention of General Melville, was cast at Carron Foundry, from which indeed the new form of cannon derived its name; and the manufacture of carronades was long the speciality of these ironworks, and it was in a great measure owing to the great extent of this branch of industry during the wars that the proprietors of the works made their large profits.

Succeeding the Carron Works the next important seat of iron manufacture sprang up in Scotland, at Wilsonstown or Cleugh, in the upper ward of Lanarkshire, and near the boundary of Midlothian. It was here, about the year 1774, that the brothers Wilson—merchants engaged in the Swedish iron trade—commenced to develop the coal deposits of the district, and soon afterwards established a foundry. This was succeeded about the years 1780—1781 by the Messrs. Wilson erecting a blast furnace, put in operation in 1781, subsequently the works were greatly extended, and in the year 1787 a second furnace was blown in.

In Mr. William Aiton's "General View of the Agriculture of the County of Ayr," * some interesting facts are gleaned bearing on the iron industries of Scotland, from which it appears that the manufacture of iron was carried on for some time, by Lord Cathcart and others at Muirkirk in the early part of the previous century. It was made from the ore dug there, and sent to Bunawe, in the county of Argyle, to be reduced into pig iron, which was afterwards brought to the works at Muirkirk, near Glasgow, where it was made into bar iron, in the last operation charred peat being used. These operations were found, however, to be too expensive, and the work was abandoned.

It is further stated by Aiton that in the year 1787 some gentlemen in Glasgow entered into a co-partnery and erected some very extensive ironworks in that parish, which were still carried on in Aiton's time by another company. The works at that time consisted of three blast furnaces for making pig iron, with a foundry and other accessory works, the number of hands employed in the above works at that time being from 300 to 400; while the

* Published in the year 1811.

mineral-field of the Muirkirk Company, at the time referred to, exceeded 2,000 acres of coal and ironstone.

In the year 1788, the Wilsonstown or Cleugh furnaces, two in number, produced 1,600 tons of coke pig iron, and the four furnaces at the Carron Works, 4,000 tons, amounting to 5,600 tons of coke pig iron in Scotland in 1788. The total production of charcoal pig iron in Great Britain the same year was 14,500 tons, and of coke pig iron, 53,800 tons, or a total make of pig iron of 68,300 tons.* Scotland at this time produced 10 per cent. of the above quantity, the average yield of her blast furnaces being 875 tons, compared with 796 tons, the yield of the furnaces of England and Wales.

The Muirkirk Works and those at Omoa, in Lanarkshire, commenced operations in the year 1788; the last named was dismantled a few years since. The former still exists. The Clyde Ironworks, near Glasgow, projected about the same year by Messrs. Edington and Co., commenced operations a few years later.

These latter works have been rendered famous by being associated with two names celebrated in the history of the metallurgical industries of Great Britain. The one, Mr. David Mushet, the other, Mr. James Beaumont Neilson. The first named entered these works as accountant in the year 1792, when he was nineteen years of age and remained till the year 1800. In the following year, while engaged in the projection of the Calder Ironworks in association with Mr. William Dixon, senior, of Govan, Mushet made the discovery of the black band ironstone, which in subsequent years exercised such an important influence in the prosperity of Scotland in her iron and other industries.

The last return quoted was for the year 1788; not again until the year 1796, when Dr. McNab's return, prepared for a Committee of the House of Commons, appears, does any reliable information throw light on the progress of this industry. The following details from Dr. McNab's return show the respective works in operation in Scotland, with the number of furnaces and the make of pig iron: side by side is given the average yield per furnace. Of the 16,086 tons of pig iron it will be observed that 900 tons was charcoal pig, the yield of the Bunawe and Goatfield furnaces.

* For details of this return, see Appendix II., p. 830.

No.	Name of Works.	No. of Furnaces.	Make of Pig Iron.	Average per Furnace.
			Tons.	Tons.
1	Carron	4	5,616	1,404
2	Wilsonstown or Cleugh . .	2	2,080	1,040
3	Muirkirk.	2	2,878	1,489
4	Clyde	3	2,216	738
5	Omoa	2	1,198	599
6	Devon.	2	1,198	599
7	Goatfield (charcoal) . .	1	300	300
8	Bunawe ,, ...	1	600	600
	Total . . .	17	16,086	

In the same year the total number of furnaces in operation in Great Britain,* was 124, producing 125,079 tons of pig iron, showing an average yield per furnace of upwards of 1,000 tons.

Towards the close of the past century, about the year 1782, the Devon Ironworks, in Clackmannanshire, were erected, singular alike in situation and construction. Sir John Sinclair, who describes them, says: † "They merit the attention of the curious in mechanics and architecture. A steep bank rises more than 90 feet from the level of the river, and is composed of a rock, or very thick stratum of limestone, very dry and uniform in its texture, and almost free from cracks and fissures. Instead of the usual method of building with stone and lime, the several parts of the works have been formed in this bank by excavations made in the rock. Two furnaces, which are each 40 feet high and 14 feet in diameter, and also the spacious arches which give access to the workmen at the bottom of the furnace, to draw off the liquid metal and slag, are cut out of the rock. The roof which covers the casting house, a room 70 feet long, 50 feet wide, and 23 feet high, is supported by the sides of the quarry, and the solid pillars of the rock that were left for the purpose in making the excavation. In like manner is formed the engine house and its apparatus, which is intended to supply the two furnaces with wind, by throwing at each vibration of the engine a sufficient quantity of air out of a large cylinder into a long gallery or close mine formed in the rock. This magazine of wind will contain 10,000 cubic feet of air, much condensed by the power of the engine, as the gallery is very closely shut up and made air-tight,

* For details see Appendix II., p. 831.

† "Statistical Account of Scotland," 1792.

having only two apertures, one to receive the supply of air from the air-pump and the other to admit a pipe that conducts the condensed air to blow the two furnaces." These works continued in operation for many years, but were stopped about the year 1858, and soon after dismantled.

Resuming inquiries with the present century it appears, as previously stated, that the Calder Ironworks commenced operations in the year 1801. These works take a prominent position in the history of the iron trades of Scotland, from the circumstance that it was here that the black band ironstone discovered by Mushet was first used as an ore of iron. The Shotts Ironworks were projected in the year 1802, under the able management of Mr. John Baird, of the Canal Basin Foundry, Glasgow, who continued to be the managing partner of the concern for upwards of 40 years. At these works in recent years Bessemer pig iron has been produced from hematite ore and with the use of raw coal.

Continuing the returns of production, the year 1806 comes next in order, when the following works and furnaces produced iron in the quantities given, to which is added the average yield per furnace:—

County.	Name of Works.	Furnaces.		Pig Iron Made.	Average per Furnace.
		Built.	In Blast.		
		Nos.	Nos.	Tons.	Tons.
Stirlingshire	Carron	5	5	7,380	1,476
Lanarkshire	Calder	2	1	1,077	1,077
"	Clyde	3	2	2,687	1,343
"	Glenbuck	1	1	790	790
"	Omoa	3	2	1,852	926
"	Shotts	1	1	2,034	2,034
"	Wilsonstown	2	1	1,381	1,381
Fifeshire	Markinch	2	0	...	...
Ayrshire	Muirkirk	3	2	3,043	1,521
Clackmannan	Devon	2	2	2,596	1,298
Argyle	Goatfield	2	0	...	...
"	Bunawe	1	0	...	...
	Total	27	17	22,840	

Comparing the above returns with those of the year 1796, it will be seen that considerable advance had been made in the yield of pig iron, to the extent of upwards of 40 per cent. The

average make per furnace being 1,270 tons, compared with 946 tons in the year 1796, equal to an increase of 12 per cent.

The make of pig iron in Great Britain in 1806, when of the 216 furnaces built 161 were in blast, was 243,851 tons.

During the first quarter of the present century there is but little to record, either in the way of greatly increased production of pig iron in Scotland or in the extension of the then existing ironworks; not until the year 1825 does it appear any new works were established.

The Monkland Iron Company led the way, about this period putting their first furnace in blast, adding a second to their works about the year 1828 or 1829. The works at Gartsherrie followed about the year 1830, when the first furnace was blown in; these works, situated at Coatbridge, near Glasgow, and projected by the Messrs. Baird and Company, are the most extensive at the present time in Lanarkshire, possessing 16 blast furnaces; the only other iron company in Scotland possessing greater resources of production is that of the Eglinton Company in Ayrshire, with 21 furnaces.

As previously stated the production of pig iron in Scotland in the year 1806 was 22,840 tons; advancing to the year 1823, it appears the production did not exceed 24,500 tons, the yield of 22 furnaces, of which the following is an account, showing the works, furnaces blowing, firms engaged in manufacture, and yield of individual works :—

County.	Name of Works.	Name of Firm.	No. of Furnaces.	Pig Iron Made.
				Tons.
Stirling .	Carron . .	Carron Iron Co. .	5	7,000
Lanark . .	Calder . .	William Dixon . .	3	4,000
,, . .	Clyde . .	Dunlop & Co. . .	3	2,500
,, . .	Omoa . .	Dalrymple & Co. .	2	2,500
,, . .	Shotts . .	Shotts Iron Co. .	1	2,000
Ayr . . .	Muirkirk . .	Muirkirk Iron Co. .	3	3,500
Clackmannan	Devon . .	Devon Iron Co. .	3	3,000
		Total . .	20	24,500

We now advance to the period when the successful experiments of Mr. James Beaumont Neilson resulted in the application of the hot blast, inaugurating a new era in the history of the iron trade and leading to greatly increased production. Neilson, to

whom we are indebted for this important invention, was educated as an engineer, and in the year 1817, at the age of 25 years, was appointed foreman to the Glasgow Gas Light Company; the great experience acquired by him in this capacity led to his being consulted by ironmasters, which gave him opportunities of gaining a great insight into the operations connected with blast furnace management. At an early period he was consulted by Mr. Dixon of the Wilsonstown Works and by the Muirkirk Iron Company, but it was at the Clyde Ironworks that his experiments were successfully carried out, the then proprietor being Mr. Colin Dunlop; eventually Neilson secured his invention by patent in the year 1828, which is entitled "Improved application of Air to produce Heat in Fires, Forges, and Furnaces." The discovery of the superior power of a hot over a cold blast in fusing refractory lumps of cast-iron was accidentally observed by Neilson while in the service, as previously stated, of the Glasgow Gas Light Company. No particular description of apparatus was given by the inventor by which the air was to be heated and conveyed to the furnace, but it was merely stated that the air may be heated in a chamber or closed vessel, having a fire under it, or in a vessel connected in any convenient manner with the forge or furnace. Dr. Percy,* referring to this important invention, says: "The advantages, however, of the hot blast with respect to the economy of fuel were so soon recognised by the Scotch ironmasters, that in the year 1835 it was in operation at every ironworks in Scotland except one, and there it was in process of introduction."

Another important invention, perfected about the year 1830, by Mr. Condie, manager of the Wilsonstown Ironworks, was the Water-Tuyere, now so generally employed, and which owes its great utility to the spirally disposed malleable iron tube contained within a mass of cast-iron. It was at the same works in the year 1808, that the Water-Tuyere was brought into use to supersede the dry-tuyere, but it was not till the year 1830, as already stated, that Mr. Condie devised and perfected the present arrangement. It was also at the Wilsonstown works that the possibility of using raw coal in the blast furnace was first solved, dating an eventful period in the history of pig iron manufacture.

The next return of pig iron production is for the year 1830, when Scotland had 24 furnaces in operation out of 27 then built,

* "Metallurgy," Iron and Steel, p. 395.

the yield of pig iron amounting to 37,500 tons. The details of which will be seen in the following abstract, giving also the average make per furnace :—

County.	Name of Works.	No. of Furnaces.	Pig Iron Made.	Average per Furnace.
			Tons.	Tons.
Stirling . .	Carron . .	5	7,000	1,400
Lanark . .	Calder . . .	4	9,000	2,250
,, . .	Clyde . . .	4	8,000	2,000
,, . .	Monkland . .	2	2,000	1,000
,, . .	Shotts . . .	1	2,000	2,000
,, . .	Wilsonstown* .	2	2,000	1,000
Ayr . . .	Muirkirk . .	3	4,000	1,333
Clackmannan .	Devon . . .	3	3,500	1,166
	Total .	24	37,500	

Comparing the production of Scotland in the year 1830 with that of the year 1823, it will be seen that the increase is 53 per cent.; the average yield of the furnaces increasing from 1,225 tons in the year 1823 to 1,480 tons in the year 1830.

It may be interesting, while considering the state of the iron industries of Scotland in the years 1823 and 1830, to note the production of the iron works in the other districts of England and Wales; to enable comparison to be made, the returns of Great Britain are appended in the annexed abstract :—

Counties.	1823.		1830.	
	Furnaces.	Pig Iron Made.	Furnaces.	Pig Iron Made.
	Nos.	Tons.	Nos.	Tons.
Durham and Northumberland . . .	2	2,379	4	5,327
Yorkshire	26	27,311	27	28,926
Derbyshire . . .	15	14,038	18	17,999
Shropshire	38	57,923	48	73,418
Staffordshire . . .	84	133,590	123	211,604
South Wales	72	182,325	113	277,643
North Wales . . .	7	13,100	12	25,000
Scotland	22	24,500	27	37,500
Total . . .	266	455,166	372	677,417

The above totals show an increase in the production of the furnaces in the seven years between 1823 and 1830 of 48 per cent.

* These works ceased operations in the year 1842.

The hot blast is so important, contributing as it did to the ironmaster's powers of increasing the blast furnace yield, that a few facts connected with its early history will possess some interest to the general reader.

Previous to the introduction of Neilson's invention, coke was largely employed in the blast furnace, now the hot blast enabled the ironmaster to employ raw coal; the saving thereby effected amounted to no less than 5 tons to each ton of pig iron made, and these advantages, taken in connection with Mushet's discovery of the black band ironstone, a furnace working hot blast and making 60 tons of iron per week, had its production raised to from 80 and 90 tons; and it is recorded that at the Calder and Wilsonstown Ironworks Neilson's invention was early put to the test, and such material aid was rendered by Mr. William Dixon, and his manager, Mr. Condie, in working and developing the merits of the invention, that the proprietors of the patent rights granted the use of the patent for several of the Calder furnaces without exacting the usual royalty charges.

From this period forward each year witnessed an increase to the resources of existing works, and the accession of many new ones; thus in the year 1833 the works at Dundyvan were projected by Mr. John Wilson, followed in the year 1836 by the Coltness Company, and the Summerlee Works in the year 1837 by Messrs. Wilsons and Co., the Carnbroe Works, in Lanarkshire, by Messrs. Allison and Co. in the year 1838, and the Langloan Works, also in Lanarkshire, near Coatbridge, by the Messrs. Addie and Co., in the year 1841. The other works projected about this period were those of Castle Hill, near Wishaw, by the Shotts Iron Company, and Govan, near Glasgow, by Mr. William Dixon, Glengarnock, in Ayrshire, near Kilbirnie, now owned by William Dixon, Limited. These works were originally intended to consist of eight blast furnaces, but up to the present time five only have been erected; of these, two have been raised considerably in height, and provision made for taking off the gas. This establishment also possesses extensive malleable iron works, capable of producing 400 tons per week of plates, bars, and rods. Advancing to the year 1843, a period of great depression in the iron industries of Great Britain, we find the following statement, showing the weekly make of the ironworks of Scotland, together with the number of furnaces built and in blast in that year:—

County.	Name of Works.	Name of Firm.	Furnaces. Built.	Furnaces. In Blast.	Weekly Make.
			Nos.	Nos.	Tons.
Stirling	Carron	Carron Iron Co.	5	3	200
Lanark	Calder	William Dixon	8	6	600
,,	Clyde	C. Dunlop & Co.	6	3	250
,,	Coltness	Coltness Iron Co.	4	3	240
,,	Dundyvan	John Wilson	9	7	750
,,	Castle Hill	Shotts Iron Co.	2	0	...
,,	Carnbroe	Allison & Co.	6	4	500
,,	Gartsherrie	William Baird & Co.	16	11	1,200
,,	Govan	Messrs. Dixon	5	5	500
,,	Langloan	Addie & Co.	3	3	400
,,	Monkland	Monkland Iron Co.	5	5	500
,,	Summerlee	Wilsons & Co.	6	3	270
,,	Shotts	Shotts Iron Co.	4	2	160
,,	Wilsonstown		2	0	...
,,	Omoa	R. Stewart	2	1	80
Ayr	Glengarnock	Allison & Co.	3	3	300
,,	Muirkirk	Muirkirk Iron Co.	4	2	180
,,	Blair	Blair Iron Co.	3	0	...
,,	Cessnock	Cessnock Iron Co.	2	0	...
,,	Henschell	Henschell Iron Co.	2	0	...
,,	Garscube	Galloway & Co.	2	0	...
Clackmannan	Devon	Devon Iron Co.	4	1	90
		Total	103	62	6,220

In computing the annual production of pig iron in Scotland from the above weekly make, and taking 50 weeks for the year, we have an annual yield of 311,000 tons. Comparing this quantity with the make in the year 1839, when of the 60 furnaces then erected in Scotland, 54 were in blast, yielding 196,566 tons of pig iron, the returns exhibit an increase between the years 1839 and 1843 of no less than 114,440 tons, equal to nearly 60 per cent.

As previously stated, the iron industries of the kingdom were passing through a period of great depression, which continued from about the year 1840 until the year 1844, when the extension of the railway system gave rise to a great demand for all kinds of iron, and brought about more prosperous times for the iron trade. About the period referred to the quotations for iron were very low and to the ironmaster comparatively unremunerative. It was about this period that the patent of Neilson of the hot blast expired, and this circumstance led to the foundation of many new

and extensive ironworks in Scotland, and to the extension of existing works. Among these may be mentioned those of Messrs. Merry and Cunninghame, of Ardeer and Glengarnock, the works at Eglinton, Lugar, and Portland, of the Eglinton Iron Company, and the works of the Dalmellington Company, all in Ayrshire. In Lanarkshire, the works of Mr. William Dixon, at Govan, and of the Shotts Iron Company, at Castlehill, were extended; while in Linlithgow, the works at Kinneil were founded by Mr. J. Wilson.

In the year 1843 the production of pig iron in Great Britain amounted to 1,215,350 tons; in 1848 it rose to 1,998,568 tons, the yield of the Scotch furnaces during the same period increasing from 311,000 tons in the year 1843, to 534,000 tons, an estimated return in the year 1848. The following is a list of the works and furnaces built and in operation in Scotland in the year 1848, together with the production of pig iron:—

County.	Name of Works.	Furnaces.		Pig Iron Made.
		Built.	In Blast.	
		Nos.	Nos.	Tons.
Stirling . .	Carron	4	3	18,000
Lanark . .	Calder	8	3	18,000
,, . . .	Carnbroe . . .	6	3	18,000
,, . .	Clyde.	7	5	30,000
,, . . .	Coltness . . .	6	4	24,000
,, . .	Castlehill	3	2	12,000
,, . . .	Dundyvan . . .	9	8	48,000
,, . .	Gartsherrie . .	16	16	96,000
,, . . .	Govan	6	4	24,000
,, . .	Langloan	6	5	30,000
,, . . .	Monkland . . .	9	9	54,000
,, . .	Omoa	4	4	24,000
,, . . .	Shotts	4	3	18,000
,, . .	Summerlee . .	6	5	30,000
Ayr	Blair	5	0	...
,, ...	Garscube	2	0	...
,, ...	Glengarnock . .	7	6	36,000
,, ...	Muirkirk	4	0	...
,, ...	Eglinton . . .	3	0	...
,, ...	Lugar	4	0	...
Clackmannan .	Devon	1	1	6,000
Fife . . .	Forth	6	4	24,000
Linlithgow . .	Kinniel	4	4	24,000
	Total . .	130	89	534,000

From the above return it appears that the production of Scotland is set down at 534,000 tons; in another return for the same year, the yield is stated to have been 539,962 tons.* The subjoined table shows the production in Great Britain in the same year:—

Districts.	Furnaces.			Pig Iron Made.
	In.	Out.	Total.	
	Nos.	Nos.	Nos.	Tons.
Northumberland	24	12	36	99,840
Yorkshire	23	5	28	66,560
Derbyshire	20	10	30	95,160
Shropshire	28	6	34	88,400
Staffordshire, North	16	3	19	65,520
Staffordshire, South	77	62	139	320,320
Wales, North	5	6	11	16,120
Wales, South	151	45	196	706,680
Scotland	89	41	130	539,968
Total	433	190	623	1,998,568

From the year 1848, to which the above return refers, great activity set in, not only in Scotland but in many iron districts of England and Wales. In Fifeshire works were founded at Lochgelly and Lumphinnans, the last-named by Messrs. A. Christie and Co., and in Linlithgowshire, the Bridgeness and Almond Works, by Mr. Henry Cadell and Messrs. Russell and Sons.

The other works in Lanarkshire erected in recent years are those at Calder Bank and Chapel Hill, near Airdrie, the property of the Monkland Iron and Coal Company, Limited, consisting of nine blast furnaces; the Quarter Works, near Hamilton, with five furnaces, belonging to Messrs. Colin Dunlop and Co.; and the Wishaw Works of the Glasgow Iron Company, with three furnaces.

Following the production of pig iron in Scotland since the year 1850, the most complete information is available, showing the number of furnaces built and in blast, together with the production of pig iron; side by side is given, for comparison, the production of the North Riding of Yorkshire, or Cleveland district, and that of Lancashire in each of the same years:—

* "Report on the State of the Population in the Mining Districts," 1848, p. 27.

Year.	Scotland.			Cleveland.	Lancashire.
	Furnaces.		Pig Iron.	Pig Iron.	Pig Iron.
	Built.	In Blast.			
	Nos.	Nos.	Tons.	Tons.	Tons.
1850	...	105	595,000	...	...
1852	...	113	775,000	...	...
1854	156	118	770,000	...	...
1856	141	127	832,000	179,400	...
1858	177	132	945,000	189,320	2,840
1860	175	131	1,000,000	248,665	81,250
1862	171	125	1,080,000	283,398	138,563
1863	169	134	1,160,000	315,197	164,110
1864	170	131	1,160,000	409,106	195,460
1865	180	141	1,163,478	486,421	204,925
1866	165	99	994,000	546,091	268,680
1867	167	112	1,031,000	640,892	318,801
1868	147	103	1,068,000	699,494	325,367
1869	165	132	1,150,000	766,410	436,662
1870	156	123	1,206,000	916,970	422,728
1871	155	127	1,169,000	1,029,885	520,359
1872	154	130	1,090,000	1,122,114	524,041
1873	156	126	993,000	1,156,431	529,271
1874	157	121	806,000	1,158,471	488,672
1875	159	116	1,050,000	1,240,243	558,780
1876	157	116	1,103,000	1,261,013	552,984
1877	152	109	982,000	1,374,582	624,189
1878	152	94	902,000	1,358,442	616,256
1879	157	96¾	932,000	1,210,091	631,343
1880	149	112	1,049,000	1,666,156	738,023

In the year 1854, of the 770,000 tons of pig iron produced in Scotland, Ayrshire contributed 249,600 tons; the Lanarkshire furnaces, 468,000 tons, and the remaining districts, 52,400 tons. In later years, the iron-making districts contributed in the following proportion:—

Districts.	Make of Pig Iron.				
	1874.	1876.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.
Lancashire	501,000	680,076	604,280	625,634	670,085
Ayrshire	210,000	360,924	256,377	276,552	345,729
Fifeshire	14,000	62,000	..	..	..
Linlithgowshire . . .	35,000		41,343	29,814	33,186
Stirlingshire . . .	16,000				
Total . . .	806,000	1,103,000	902,000	932,000	1,049,000

The average annual yield of the Scotch blast furnaces in the

year 1850, was 5,700 tons, increased in the year 1860 to 7,630 tons, 9,800 tons in the year 1870, and 9,366 tons in 1880.

The annexed is a complete list of the works, owners, furnaces built and in blast in Scotland in the year 1880:—

No.	Name of Works.	Owners.	Furnaces. Built.	Furnaces. In Blast.
	Ayrshire—		Nos.	Nos.
1	Ardeer, Stevenston	Merry and Cunninghame, Lim.	5	3
2	Glengarnock, Kilbirnie	,, ,, ,,	9	6
3	Eglinton, Glasgow	Eglinton Iron Co.	7	5½
4	Lugar, ,,	,, ,,	5	4
5	Muirkirk, ,,	,, ,,	3	3
6	Portland, ,,	,, ,,	6	4
7	Dalmellington, Glasgow	Dalmellington Iron Co.	8	7
		Total of Ayrshire	43	32½
	Lanarkshire—			
1	Calder	William Dixon, Limited	6	4
2	Govan, Glasgow	,, ,,	5	5
3	Carnbroe, Coatbridge	Merry and Cunninghame, Lim.	6	3
4	Castlehill	Shotts Iron Co.	3	3
5	Shotts	,,	5	5
6	Clyde	James Dunlop & Co.	5	5
7	Quarter, Hamilton	Colin Dunlop & Co.	5	5
8	Coltness	Coltness Iron Co.	12	10
9	Gartsherrie, Coatbridge	William Baird & Co.	14	12
10	Langloan, ,,	Robert Addie & Sons	7	7
11	Calder Bank, Airdrie	Monkland Iron and Coal Co., Lim.	6	5
12	Chapelhill, ,,	,, ,, ,,	3	3
13	Summerlee	Summerlee Iron Co.	8	6
14	Wishaw	Glasgow Iron Co.	3	3
		Total of Lanarkshire	88	76
	Fifeshire—			
1	Lochgelly	Lochgelly Iron and Coal Co., Lim.	4	0
2	Lumphinnans, Lochgelly	A. Christie & Co.	2	0
		Total of Fifeshire	6	0
	Linlithgowshire—			
1	Kinniel, Boness	George Wilson & Co.	2	1
2	Bridgeness, ,,	Henry Cadell	2	0
3	Almond, Causewayend	James Russell & Sons	3	1
		Total of Linlithgowshire	7	2
	Stirlingshire—			
1	Carron, Falkirk	Carron Iron Co.	4	2
	Argyleshire—			
1	Lorn	Harrison, Ainslie, & Co.,	1	0
		Total of Fifeshire, Linlithgowshire, Stirlingshire, and Argyleshire	18	4
		Total of Scotland	149	112½

Distribution of Scotch Pig Iron and Prices.—The ironworks of Scotland are most favourably situated for the distribution of the products of her iron furnaces, possessing at easy distances two coasts, with numerous shipping ports and ample railway and canal communication; they are also close to the rivers Clyde and Forth, both navigable for the greater part of their course. The exports of pig iron in 1830, when the total production of Scotland did not exceed 37,500 tons, varied from 8,000 to 9,000 tons. In 1845, out of a production of 500,000 tons, the exports were only 56,761 tons, about one-tenth and less in proportion than in the year 1830. Between the years 1840 and 1845, a great impetus was given to the iron trade by the extension of the railway system of the United Kingdom, the home consumption absorbing the additional production. The increased number of works and more active competition existing at this period, coupled with a now more restricted home market, led to a first fall in prices, which set in about the year 1841, and continued till the year 1853. In the following table appears the average prices of pig iron in Scotland from 1830 to 1862; the prices since that date are given on page 747:—

Year.	Average Price. £	s.	d.	Year.	Average Price. £	s.	d.
1830	5	0	0	1848	2	4	5
1831	4	10	0	1849	2	6	1
1832	4	10	0	1850	2	4	5
1833	4	0	0	1851	2	0	3
1834	4	5	0	1852	2	5	4
1835	4	10	0	1853	3	1	6
1836	6	15	0	1854	3	19	9
1837	4	10	0	1855	3	10	9
1838	4	0	0	1856	3	12	6
1839	4	10	0	1857	3	9	2
1840	3	15	0	1858	2	14	5
1841	3	0	0	1859	2	11	11
1842	2	10	0	1860	2	13	9
1843	2	16	0	1861	2	9	3
1844	2	14	9	1862	2	13	0

Previously, in the year 1810, the average price of Scotch pig iron per ton was £9 5*s.*; in 1815 it receded to £7 15*s.* per ton, and in 1820 to £7, rising again in 1825 to £11 per ton.

Since the year 1845 the distribution of Scotch pig iron to foreign countries and coastwise to other ports in the United Kingdom has gone on increasing. In the following table appear

the quantities under each of the above heads, also the stocks of pig iron in warehouses at the end of each year :—

Year.	Exported.		Total.	Stocks.
	Foreign.	Coastwise.		
	Tons.	Tons.	Tons.	Tons.
1845	56,671	...	...	240,000
1846	119,107	192,893	312,000	144,000
1847	143,460	227,005	370,465	89,000
1848	162,114	227,870	389,984	90,000
1849	153,200	221,943	375,143	196,000
1850	134,710	189,490	324,200	200,000
1851	192,610	260,090	452,700	300,000
1852	224,370	210,530	434,900	360,000
1853	318,020	316,980	635,000	450,000
1854	283,903	301,097	585,000	216,000
1855	243,108	295,000	538,108	132,000
1856	258,589	245,000	503,589	130,000
1857	294,232	233,768	528,000	90,000
1858	274,000	280,000	554,000	196,000
1859	254,245	312,755	567,000	350,000
1860	255,628	321,372	577,000	390,000

In the year 1845—46 a new era opened out for the products of the Scotch blast furnaces, the markets of France, Germany and the United States contributing to the greatly increased exports apparent in those years. In 1848, in Scotland as elsewhere, industrial and commercial affairs were more or less affected by the disturbed state of affairs prevailing in Europe.

Following the course of events at this period a more encouraging state of trade appears in the years 1852—53, when prices ruled higher, the demand at home and abroad increasing. This condition was however of short duration, inasmuch as the crisis then taking place in America and the condition of affairs in Europe materially checked the prosperity which had set in about this time in the iron and other industries of the country.

It would give an inadequate idea of the condition of the Scotch iron trade at this eventful period, did we omit the statistics bearing on the local consumption of pig iron in Scotland; we therefore give the following table, distinguishing the quantity of pig iron employed in the foundry, from that used in the malleable ironworks for conversion into the various forms of iron applicable to the construction of iron vessels, bridges, and machinery, be-

tween the years 1846 and 1860, increasing from 280,000 tons in the first to 355,000 tons in the last-named year:—

Year.	Foundries.	Malleable Iron Works.	Total Home Consumption.
	Tons.	Tons.	Tons.
1846	200,000	80,000	280,000
1849	...	...	221,000
1850	...	...	225,000
1851	...	...	250,000
1852	...	...	250,000
1853	125,000	180,000	305,000
1854	116,000	170,000	286,000
1855	125,000	175,000	300,000
1856	133,000	203,000	336,000
1857	155,000	160,000	315,000
1858	146,000	132,000	278,000
1859	190,000	150,000	340,000
1860	200,000	155,000	355,000

With regard to the distribution of Scotch pig iron, it will be sufficient to give the quantities, under the several heads, for the following years; these, although indicating a marked increase, also exhibit considerable fluctuation, but not more than might be expected from the variable conditions to which the iron trade has been subject during the years given:—

Year.	Rail to England.	EXPORTED.		HOME CONSUMPTION.	
		Foreign.	Coastwise.	Foundries.	Malleable Iron Works.
	Tons.	Tons.	Tons.	Tons.	Tons.
1868	22,200	324,018	238,922	208,000	179,800
1869	21,911	388,639	240,450	240,000	207,000
1870	35,174	388,842	230,984	298,000	208,000
1871	54,027	512,479	303,494	275,000	190,000
1872	74,372	616,933	224,695	270,000	200,000
1873	81,089	398,850	214,061	230,000	143,000
1874	50,093	296,803	166,104	193,000	124,000
1875	73,491	368,453	174,056	205,000	155,000
1876	70,058	303,752	166,190	195,000	175,000
1877	59,937	274,409	170,654	175,000	160,000
1878	38,472	233,908	161,620	153,500	140,500
1879	23,482	340,385	200,133	155,045	146,955
1880	29,952	440,200	200,848	189,000	195,000

Malleable Ironworks, Mills and Forges.—Many of these works are some of the most extensive in the kingdom, possessing the necessary appliances for manufacturing the heaviest descrip-

tion of ironwork; consisting of crank shafts, propeller shafts, stern posts, rudder posts, &c., and possessing in addition rolling mills and steam hammers for manipulating large masses of malleable iron, besides lathes of various kinds for reducing the forgings to a more or less finished condition. The Lancefield Works, near Glasgow, possess great resources. It was at this forge that all the great forgings for the *Great Eastern* were made, the propeller shaft of which was 47 feet in length and weighed 35 tons; the crank shaft, 31 tons, and the stern frame, 25 tons. These works also have puddling, scrap, and forge furnaces, rolling mills, and steam hammers of various sizes, the hammer-head of the largest exceeding 7 tons in weight. Another extensive establishment at Parkhead contains the necessary appliances for the heaviest forgings, as well as for ship and boiler plates and other varieties of finished iron. It was at Parkhead that the heavy double crank shaft of the *Monarch*, weighing upwards of 30 tons, was forged. These works possess 46 puddling furnaces and 3 rolling mills, are furnished with 14 steam hammers, the heads varying in weight, the heaviest exceeding 7 tons. The puddling furnaces each make on an average 6 charges of 4 cwt. each per day of 10 hours, the charges producing about 20 cwt. of puddled bars. The puddled bars are shingled with 2½-ton hammers, and are rolled down in a pair of 24-inch grooved and collared rolls, which keep the bars to an uniform width. These rolls are described as worked by a pair of horizontal engines, with cylinders 30 inches in diameter and 60 inches stroke, at the rate of 40 revolutions per minute, and worked by steam with 45 lb. pressure; the crank shaft of the engine makes 30 revolutions per minute. The same engines drive the other rolling mills. The mill bars are used for piling and forging, or they are piled and rolled for the production of plates; the best qualities of plate are piled and rolled a second time, and then reheated and finished, each successive reheating consuming from 10 to 18 cwt. of coal per ton of iron, the loss of material in the operation being about 5 per cent.

The works of the Glasgow Iron Company, at St. Rollox and Motherwell are large establishments, with an aggregate of 87 puddling furnaces and 12 rolling mills, besides reheating furnaces, &c. The Saint Rollox Works is capable of producing from 100 to 200 tons per week, of hoops, bars, nails, rods and small

merchant iron. The works at Motherwell are capable of producing from 500 to 600 tons per week, of hoops, nails, rods, iron sheets, plates, rails, &c. These works were amongst the first in Scotland in which the regenerative furnaces of Dr. Siemens were employed. The Glasgow Ironworks, belonging to the same company, were established about the year 1845, and are capable of producing from 300 to 400 tons of finished iron per week.

The annexed table gives the names of the malleable ironworks in Scotland, the owners, the numbers of puddling furnaces and rolling mills, according to the last published return :—

SCOTLAND.

No.	Name of Works.	Name of Firm.	Nearest Port or Railway Station.	No. of Puddling Furnaces.	No. of Rolling Mills.
1	Blockhairn, St. Rollox	Hannay & Sons	Glasgow	..	..
2	Clifton	John Wylie & Co.	Coatbridge	20	2
3	Clydesdale	Clydesdale Iron Co.	"	..	..
4	Coats	Thomas Jackson	"	..	..
5	Coatbridge	Hugh Martin & Sons	"	7	2
6	Crown	William Tudhope	"	12	2
7	Dalzell	David Colville	Motherwell	19	2
8	Drumpeller	Henderson and Dimmock	Coatbridge	18	3
9	Globe	A. and T. Miller	"	6	1
10	Glasgow	Glasgow Iron Co.	Glasgow	37	4
11	Motherwell	" "	"	50	8
12	Milnwood	John Aiton & Co	Holytown	6	2
13	Govan	William Dixon	Glasgow	..	..
14	Calder Bank	Monkland Iron and Coal Co.	"	46	6
15	Mossend	Mossend Iron Co.	Holytown	..	..
16	North British	Thomas Ellis	Coatbridge	30	4
17	Parkhead	W. and J. Beardmore	Parkhead	9	4
18	Phœnix	John Spencer	Coatbridge	19	3
19	Rochsolloch	Rochsolloch Iron Co.	Glasgow	11	2
20	Muirkirk	Eglinton Iron Co.	"	9	2
21	Excelsior	John Williams & Co.	Wishaw	30	4
	Total of Scotland	. . . .	. . . .	329	51

For the manufacture of steel the Atlas Bessemer Steel Works of the Glasgow Company possess two converters, each of a capacity of 3 tons. The Steel Company of Scotland and the Moss End Iron Company, Holytown, being manufacturers of steel by the Open-hearth Steel Melting process.

An important addition to the steel industries of Scotland is recently announced in the opening of the Dalziel Steel Works, Motherwell. These extensive works, belonging to the firm of Mr. David Colville, have been in course of construction during the past twelve months, and commenced the manufacture of steel in February last. The works comprise 32 Siemens' gas producers, with large wrought-iron overhead conducting tubes for the gas.

One main leads to the melting department and another to the re-heating furnaces of the mill department. The melting shop contains four 12-ton Siemens' steel melting furnaces, capable of producing 500 tons of steel ingots weekly, and one accessory combined sand and manganese furnace. The ingots are handed over to the mill department by two steam cranes, capable of lifting 6 and 10 tons respectively. The ingots are then re-heated in two large gas furnaces and reduced from 14 inches thick to slabs of 4 or 5 inches in thickness by a powerful steam hammer, the cylinder of which is 33 inches in diameter, with an 8-foot stroke. The anvil consists of a huge iron casting weighing about 140 tons, mounted by a smaller one, with a steel face, in all weighing over 150 tons. The weight of the tap, piston and rod is 12 tons, and with a working steam pressure of 80 lbs. per square inch, the hammer is capable of giving a blow considerably over 400 foot tons.

The slabs thus consolidated are cut into sizes suited for the plates required, are again re-heated in other three large Siemens' gas furnaces, and then again passed through the plate mill. In a central position of the mill floor are placed a pair of powerful Ramsbottom reversing mill engines, the cylinders of which are 40 inches in diameter, stroke 4 feet 6 inches, and worked with 80 lbs. of steam. The engines are fitted with the Allan link motion, and are placed under the driver's easy control by means of steam and cataract reversing cylinders. On the right hand side of the driver is placed the plate mill, with two pairs of rolls, 8 feet long by 28 inches diameter, the one pair being chilled, the other grain, and capable of rolling plates up to 93 inches in width by almost any length and thickness. On the left hand side is placed a 27-inch bar mill, consisting of three pairs of rolls, and capable of rolling the heaviest sections of angle, bars, &c. Both mills, like the engines, are of the most massive proportions throughout, the forgings and gearing being almost wholly of Siemens' steel. The machine for shearing the plates to the exact dimensions required is also of a massive description, the steel shearing blades are 10 feet in length, with a stroke of 12 inches, and capable of shearing steel plates 1½ inches in thickness by 7 feet broad, through at one stroke. The machine has also combined a scrap shears, and is driven by a combined steam engine of 16 inches cylinder by 20-inch stroke, working with 80 lbs. steam. There are four boilers for supplying steam

to the various machinery of combined flue and multitubular type, constructed entirely of Siemens' steel, and worked at a pressure of 80 lbs. The mechanical and chemical testing houses adjoin the works. The testing machine is capable of testing up to 50 tons on the piece, the whole operation being entirely done by steam power. The roofing covers an area of over 5,490 square yards, is constructed entirely of wrought iron and galvanised corrugated sheet iron covering, and is supported on cast-iron columns; the works occupying an area of about 14 acres of ground.

Production of Malleable Iron in Scotland.—The steady progress of this branch of industry will be seen in the annexed table, giving the returns for 15 years, also the average price of bars during the same period; side by side appears, in each of the same years, the average, highest and lowest prices of Scotch pig iron in the Glasgow market:—

Year.	MALLEABLE IRON.		SCOTCH PIG IRON.		
	Quantities.	Per Ton.	Average.	Highest.	Lowest.
	Tons.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1864	163,500	8 12 6	2 17 4	3 4 10	2 10 3
1865	173,890	7 15 0	2 14 9	3 1 9	2 9 8
1866	155,231	7 15 0	3 0 6	3 18 2	2 12 6
1867	143,800	7 0 0	2 13 6	2 14 11	2 11 10
1868	179,626	6 15 0	2 12 9	2 13 8	2 12 1
1869	206,960	7 0 0	2 13 3	2 17 0	2 10 8
1870	199,353	7 10 0	2 14 4	3 0 0	2 11 2
1871	200,131	8 0 0	2 18 11	3 10 0	2 11 6
1872	223,377	12 5 0	5 1 10	6 9 3	3 14 7
1873	189,312	13 10 0	5 17 3	6 17 9	5 5 9
1874	180,000	10 15 0	4 7 6	5 6 3	4 1 6
1875	196,000	8 15 0	3 5 9	3 17 0	2 17 6
1876	236,000	7 15 0	2 18 6	3 4 8	2 16 3
1877	218,000	7 0 0	2 14 4	2 17 2	2 12 0
1878	195,000	6 10 0	2 8 5	2 11 0	2 3 3
1879	222,000	6 0 0	2 10 4	3 0 5	2 0 6
1880	292,000	6 0 10	2 14 6	3 13 3	2 4 5

The manufacture of malleable iron in Scotland is of comparatively recent date, the industry having been commenced in the neighbourhood of Glasgow about the year 1839; in 1845 the total production of the works amounted to but 35,000 tons, increased to 80,000 tons in the year 1850, and in the year 1861 to 122,500 tons; the average price of bar iron at this period

ranging as high as £7 per ton. In the year 1872, remarkable alike for the high prices which then ruled as well as for increased production, the make amounted to 223,377 tons, but even this was eclipsed in the year 1876, when the production increased to 236,000 tons, since which a slight falling off appears, until the year 1880, when the returns show a production of 292,000 tons, the largest on record.

Coal consumed in Malleable Ironworks in Scotland.—The quantities of coal used in these works in Scotland since the year 1872 has been as follows :—

Year.	Coal Used.	Year.	Coal Used.
	Tons.		Tons.
1872	415,000	1876	439,720
1873	360,517	1877	411,854
1874	345,226	1878	370,985
1875	373,512	1879	409,527

And in the year 1880 the coal consumed in manufacture amounted to 537,508 tons.

Coal and Iron Ore used in Manufacture.—It is recorded in the survey of Ayrshire that towards the close of the last century on the estate of the Muirkirk Iron Company, 9 tons of coal was considered sufficient to make 1 ton of the best pig iron. Advancing to the year 1840, it appears on the authority of Mr. Porter, F.R.S.,* that the 241,000 tons of pig iron made in that year consumed 723,000 tons of coal in its manufacture, or 3 tons of coal to each ton of pig iron made. Again, in the years 1854 and 1860, economy appears in the consumption of materials employed, as shown in the annexed items :—

Materials.	1854.	1860.
	Tons. Cwts.	Tons. Cwts.
Calcined ores	1 12	1 14
Large coal	2 5	2 2
Small coal	0 16	0 10
Limestone	0 7	0 9

Mr. St. John V. Day, C.E.,† writing in the year 1876, referring to the Almond Ironworks, near Falkirk, gives some interesting facts showing the economy attained at these works. "The fur-

* "Progress of the Nation."

† "Iron," Dec. 2, 1876, p. 714.

nace has a height of 72 feet, and owing to the character of the coal at Almond a portion of it requires to be coked in order to get the furnaces to drive, and it is so used in the high as well as the low furnaces. The quantity of coal and coke used per ton of pig iron varies with the quantity of hard splint coal supplied from the pits. At the time referred to, the fuel used was half coal and half coke, and it appears that over a series of years, using the same burdens, the 72-feet furnaces had secured an economy to the extent of 10 cwt. of fuel to each ton of pig iron made, as compared with a furnace at the same works 50 feet in height. The average quantity of fuel, computed into coke, put in the 72-feet furnace, (blast heaters and boilers excepted), being 22¾ cwt. The ironstone (calcined) and ore being 37 cwt. per ton of pig."

"In the 50-feet furnace the consumption of coke was 29 cwt., and ironstone, 38¼ cwt. per ton of pig. The temperature of the blast at the Almond works is about 800° Fahr.; the average weekly make 200 tons. In the blast heaters the quantity of dross used is 4½ cwt., and in the boilers for driving the blowing engines, 3¼ cwt. per ton of pig iron. The pressure of blast for the 50-feet furnace is 2·5 lbs. per square inch, and for the 72-feet furnace, from 3 to 3·25 lbs. per square inch."

While referring to the Almond Works we must not omit to notice the system of coking coal carried on there. "The novelty consists in forcing either heated or cold air into the space above the upper surface of the coal being coked, thus burning the gases inside the oven as they are evolved, and thereby promoting the coking process. In working these ovens they are charged and ignited in the ordinary manner, and so soon as the heat has evolved sufficient gas and ignited it, the air is turned on and continued in regulated quantity so long as gas is given off by the coal, care being taken that the mixture of air and gas shall always contain an excess of carbon, so as to prevent the ignition of that portion of the solid carbon which goes to form coke. In practice it is found that the quantity of air is always largest at the beginning of the charge and gradually diminishes to the close. So soon as the gas is all evolved the coke is either allowed to cool down, or is watered out and drawn."

The introduction of Ferrie's Patent has also greatly contributed to economy in the use of fuel; the process consists in dividing

the upper part of a blast furnace using raw coal into a series (about four) of vertical retorts, arranged with flues all round them, through which a portion of the gases pass and wherein they burn, the heat thereby developed being utilized in coking the coal and calcining the ironstone and limestone. In this manner it has been found practicable, not only to utilise all the waste gases from a blast furnace using raw coal, but owing to the frictional support which the materials receive in their descent from the sides of the retorts, Mr. Ferrie has succeeded in carrying a column of materials or burthen of about 83 feet in height. The results of Mr. Ferrie's observations on iron smelting in his furnace are thus referred to. He says, "The quantity of coal used to the ton of iron varies with the ores employed, but this quantity in practice is from 35 to 40 cwt. to the ton of iron. The quantity of coal increases as the quantity of black band in the charge decreases, and *vice versâ*. When the quantity used to the ton is 35 cwt., the mixture of ores will be in the proportion of ⅔ black band and ⅓ clay band. An open furnace, 45 to 50 feet high, working on similar materials, will consume from 52 to 56 cwt. of coal to the ton of iron." In addition to the advantages claimed for the above arrangements, it is stated that, "In addition to the saving of coal noted above, that there is a saving of fuel in raising steam and heating the blast."

Before considering the total quantities of coal and ores employed in the furnaces of Scotland during the past ten years, the following reliable data presents some important details of the materials employed in the Gartsherrie Ironworks twenty years ago, when of the 16 furnaces built 14 were in blast, making 97,156 tons of pig iron, and consuming materials in the annexed quantities, to which is added the average quantity per ton:—

Materials Used.	Quantities.	Average per Ton.			
	Tons.	Tons.	Cwts.	Qrs.	Lbs.
Calcined ironstone	162,784	1	13	1	15
Coal	278,983	2	17	1	0
Limestone	49,794	0	10	1	0
Total materials . .	491,561	5	0	3	15

In the Castlehill Ironworks of the Shotts Iron Company in the same year, the production of pig iron amounted to 13,673

tons, in the manufacture of which the following materials were employed:—

Materials Used.	Quantities.	Average.			
	Tons.	Tons.	Cwts.	Qrs.	Lbs.
Coal used	36,347	2	13	0	20
Calcined clay band . . .	19,489	2	0	0	0
,, black band . .	6,941				
Hæmatite ore	2,605	0	4	0	0
Limestone	8,918	0	13	0	0
Total materials . .	74,300	5	10	0	20

Another return, the aggregate of four ironworks in Lanarkshire, producing also in the year 1858, some 201,174 tons of pig iron, presents the following details; the works referred to at the time possessed 29 furnaces, of which 25 were in blast, consuming the materials given:—

Materials Used.	Quantities.	Average.			
	Tons.	Tons.	Cwts.	Qrs.	Lbs.
Calcined ironstone	351,452	1	13	3	20
Coal	544,873	2	14	0	0
Limestone	83,915	0	9	0	0
Total materials . .	980,240	4	16	3	20

It therefore appears from the above figures that in the year 1858 the proportions of materials employed were regular, the difference in the amount of calcined ironstone being due to the variable proportion in each case of black band and clay band ores. The loss by calcination of black band may be generally set down at 50 per cent., and of clay band ironstone at 30 per cent. The average yield of the furnaces per annum being respectively, Gartsherrie, 6,966 tons; Castlehill, 6,836 tons; and the Lanarkshire group of furnaces, 8,047 tons.

Mr. Ralph Moore, in his interesting paper on black band ironstone, read before the Royal Scottish Society of Arts in the year 1861, gives the average quantity of materials used to make a ton of pig iron as follows:—Calcined black band, 34 cwt., coals, 50 cwt., dross, 13 cwt. and limestone, 12 cwt., making in all a total of 109 cwt. of material to each ton of pig iron made.

Advancing to the year 1872, when information was obtained by the Committee of the House of Commons appointed to inquire into the causes leading to the extravagantly high price of coal ruling at that period, the following figures are available, showing the quantity of coal used in the manufacture of pig iron, to which is appended the total quantity of iron ore employed:—

Year.	Pig Iron Made.	Coal Used.	Iron Ore Used.
	Tons.	Tons.	Tons.
1872	1,090,000	3,215,000	2,325,000
1873	993,000	2,730,000	2,194,000
1874	806,000	2,143,199	2,035,000
1875	1,050,000	2,950,000	2,400,000
1876	1,103,000	3,050,000	2,575,000
1877	982,000	2,672,638	2,385,000
1878	902,000	2,244,813	2,490,000
1879	932,000	2,256,189	2,560,000
1880	1,049,000	2,542,055	2,628,610

The economy in the consumption of fuel has gone on steadily in the Scotch furnaces since the year 1872, when the average consumption of coal to each ton of iron made was 55 cwt., decreasing to 49½ cwt. in the year 1878, and 48½ cwt. in the years 1879 and 1880. The average consumption in Great Britain being 51 cwt. in 1873, decreasing in 1877 to 46 cwt.; in 1878 to 44½ cwt.; in the year 1879 to 44 cwt., and in 1880 to 43½ cwt.

The annexed table furnishes the approximate quantities of iron ore used in the blast furnaces of Scotland between the years 1872 and 1880, distinguishing the places from which it was received:—

Year.	Scotland.	Foreign.	Lancashire.	Cumberland.	Ireland.	Total.
	Tons.*	Tons.	Tons.	Tons.	Tons.	Tons.
1872	2,192,481	50,024	7,474	75,021	...	2,325,000
1873	2,021,868	60,358	7,075	104,699	...	2,194,000
1874	1,892,925	54,175	6,309	81,591	...	2,035,000
1875	2,165,313	83,986	7,247	141,954	1,500	2,400,000
1876	2,345,432	73,367	7,699	146,723	1,779	2,575,000
1877	2,126,067	125,985	9,733	121,013	2,212	2,385,000
1878	2,371,762	61,168	5,731	49,859	1,480	2,490,000
1879	2,480,863	51,370	6,060	19,746	1,961	2,560,000
1880	2,430,000	134,267	16,542	44,820	2,981	2,628,610

* These quantities also include a small proportion of calcined stone, purple ore, and forge and mill cinder from the Malleable Iron Works.

Iron Shipbuilding.—There is yet another important branch of the iron industries of Scotland to refer to, that of iron shipbuilding. As soon as iron was found a suitable material for the construction of our mercantile marine, this industry soon attained immense proportions in Scotland, the banks of the Clyde being rapidly studded with iron shipbuilding yards. These yards may be said to commence at the termination of the quays and wharves of Glasgow, and they recur at intervals for miles along both banks of the river. The first application of iron to shipbuilding was in the construction of canal boats. Some half a century since the Horsley Company of Staffordshire constructed a sea-going steamer, and a few years later the same company constructed another vessel to ply on the river Shannon, in Ireland. It was not, however, till the year 1830 that the first iron steamer was constructed on the Clyde. This was the *Anglia*, of 30 tons burden, which plied on Lake Eck, *en route* to Inverary. The *Fairy Queen*, also of 30 tons burden, being the first iron steamer plying on the Clyde, was built in 1831. This last-named vessel was constructed in the Old Basin, some mile and a half distant from the Bromielaw, was launched into the Clyde, and propelled by an oscillating engine.

The *City of Glasgow* appears to have been the earliest example of the new form of iron ship of any size; this vessel was built in the year 1850, of 1,609 tons, and was propelled by a screw.

The earliest paddle steamer constructed of iron was the *Royal Sovereign*, of 447 tons, and plied between Glasgow and Liverpool, while of sailing ships, the *Iron Duke*, of 393 tons, was constructed about the year 1840, and sailed from Glasgow to India; and in the year 1842 the schooner-rigged sailing ship, *Glasgow*, of 100 tons, plied between the last-named place and Rotterdam, *viâ* the Forth and Clyde Canal.

The foregoing sketch shows the rise and progress of iron shipbuilding on the Clyde; it will be remembered, however, that this important industry is also pursued with vigour and success in Aberdeen, Dundee, Leith, and other places on the Fifeshire coast. For many of the above facts our acknowledgments are due to the interesting and historical paper on this subject by Mr. D. Rowan, of Glasgow, read at the Glasgow Meeting of the Iron and Steel Institute in 1872.

The remarkable development of this industry is due to the

boundless resources of coal and ironstone within easy distance of the Clyde; the iron ore being wrought, reduced to the metallic state, rolled and finished in those extensive works to which attention has been previously directed.

The earliest available statistics at hand showing the tonnage of iron vessels launched, and under contract, and on the stocks in the Clyde shipbuilding district, will be seen in the annexed table:—

Year.	Tonnage Launched.	On Stocks and Under Contract.	Year.	Tonnage Launched.	On Stocks and Under Contract.
	Tons.	Tons.		Tons.	Tons.
1863	124,000	140,000	1872	230,347	247,345
1864	178,505	105,957	1873	232,926	192,608
1865	153,932	109,404	1874	266,800	...
1866	124,513	71,869	1875	228,200	...
1867	108,024	124,082	1876	204,770	...
1868	169,571	134,818	1877	168,000	...
1869	192,310	140,199	1878	215,640	...
1870	180,401	180,175	1879	174,570	...
1871	196,229	301,809	1880	236,579	...

The Clyde owes much of its prosperity to the invention of the dredging machine, and the shipbuilders on its banks do a considerable trade in building dredges and numerous appliances for improving navigation. It may be further added, that though the practicability of constructing vessels of iron had been successfully tested, it was not until the year 1838 that it was used in the hull of any vessel of large size.

CHAPTER XXII.

IRON INDUSTRIES OF IRELAND.

Description of the Ironstone Measures of the Northern Coal-fields, Leitrim, Tyrone, Antrim—Analyses and Production of Coal—Southern Coal-fields, Leinster, Castlecomer, Kilkenny—Analyses and Production of Coal—Iron Ore Deposits (Tertiary Age) county Antrim—Magnetic Ores, county Wicklow—Ores of county Cavan—Analyses and Production of Ore—List of Iron Mines in 1880, and details of Production—Pig Iron Manufacture—Works at Drumshambo—Account of the Arigna Iron Works—Materials employed in Manufacture—Production of Pig Iron in 1856.

Iron Industries, Northern Districts (*Leitrim, Tyrone, and Antrim*):—**Ironstone Measures of the Leitrim Coal-field.**—Sir Robert Kane * refers to the "Iron Mountain (Slieve-a-Nierin), on the eastern shore of Lough Allen, as a hill of considerable elevation, and describes it as consisting of alternate beds of sandstone and slate clay, resting upon the basis of the upper limestone. The great bed of slate clay varies from 300 to 500 feet in thickness. In this clay the nodules of ironstone are disseminated in abundance, and the rains washing away the softened and decomposing clay, the balls of iron ore are carried down to the shore of the lake, whence, and from the beds of the rivulets, they are collected by the peasantry and brought to the works for use. At the base of this mountain on the eastern side of the outlet of the lake lies Drumshambo, where this ore was formerly smelted." In purity this ore is said to be somewhat superior to that which is found on the western side.

The stratification of the country on the western side of Lough Allen in the Arigna district is similar to that already described in the Iron Mountain, "Resting on the limestone of the surrounding country occurs the great bed of slate clay, 600 feet in thickness, which contains numerous beds of ironstone from half an inch to two feet in thickness. Their number is, as Sir R. Griffith mentions, almost incredible, but the most important occur from

* "Industrial Resources of Ireland," 2nd edit., p. 133.

200 to 300 feet above the limestone, while the thin beds are described as being in most cases the best; that of Altagowlan, which is a foot thick, was amongst the richest ironstone Sir R. Griffith ever saw. The usual form is that of nodules, in size from an egg to that of a bull's head, but it forms also strata or sheets of considerable extent."

In a report on the Arigna district in 1830, made to the Directors of the Company by Mr. Twigg, that gentleman observes, "The ironstone mines have been examined and the result found extremely favourable. A greater variety of ironstones I never met with, from which, by a proper admixture and good management, I have no hesitation in saying that pig iron of best marks, and fit for foundry work of every kind, may be obtained. The iron mines begin in Rover and continue for two miles and a half. I measured several of the beds to more than two feet thick, in some places laid bare in the ravines, and in the bed of the Arigna river we can get any quantity at the shortest notice." *

Analyses of the Ironstones.—The annexed analyses of numerous specimens obtained from different portions of the Arigna district, appear in their detailed character and composition as follows:—

CLAY IRONSTONE NODULES FROM ARIGNA.†

Constituents.	No. 1.	No. 2.	No. 3.
Protoxide of iron	53·65	54·42	51·52
Lime	...	2·23	0·69
Magnesia	...	2·02	1·55
Alumina	1·00	1·43	...
Insoluble clay	12·43	8·65	15·50
Carbonic acid	32·92	31·25	30·74
Total	100·00	100·00	100·00
Loss by roasting	31·50	30·90	30·70
Metallic iron per cent.	41·70	42·30	40·00

Of the veins of ironstone two specimens were analysed, taken *in situ*; they gave:—

* "Industrial Resources of Ireland," 1845, 2nd edit., p. 135.
† *Ibid.*, p. 135.

Constituents.	No. 4.	No. 5.
Protoxide of iron	47·28	49·94
Lime	1·26	3·75
Magnesia	2·23	3·79
Alumina	1·59	0·87
Insoluble clay	18·46	9·08
Carbonic acid	29·18	32·57
Total	100·00	100·00
Loss by roasting	32·14	29·80
Metallic iron, per cent.	37·70	38·80

Sir Robert Kane adds that, as none of these were picked specimens, the average of all of them may be fairly calculated as the material available on the large scale at Lough Allen, and the mean of the above five analyses gives:—

RESULTS TABULATED.

Protoxide of iron	51·36
Lime	1·59
Magnesia	1·92
Alumina	0·98
Insoluble clay	12·82
Carbonic acid	31·33
Total	100·00
Loss by calcining	31·33
Metallic iron, per cent.	40·00

It therefore appears that these ironstones are equal to the best argillaceous ores of South Staffordshire, or South Wales, and are only surpassed by the Black Bands of the Clyde valley in Lanarkshire.

Ironstones of the Tyrone Coal-field.—In the shales and fine clays of the middle series of coal measures of Dungannon there is a good deal of ironstone occurring both in beds and nodules; the former, in one or two instances, from one to two feet thick, the latter abundant. None of them have been worked to any extent, so far as is known. They have the usual composition of clay ironstones, and contain about the average per-centage of iron. Traces of an old furnace are found in the townland of Derry near the road leading from Derryvale to Stewartstown, and a quantity of slag lies about. It is possible, therefore, that some of the

ironstones above the Derry coal were formerly smelted. Mr. Hardman, who has examined some of them, both for the amount of iron, and the presence or absence of sulphur and phosphorus, gives the annexed results. The specimens were all obtained from the neighbourhood of Coal Island :—*

ANALYSES OF IRONSTONES, DUNGANNON COAL-FIELD.

No. 1. Thin seam of ironstone from above the Shining Seam.†
Metallic iron . . . . . . 35·50 per cent.
Neither sulphur nor phosphorus present.

No. 2. Ironstone nodules from Gortnaskea Coal.
Metallic iron . . . . . . 34·40 per cent.
Neither sulphur nor phosphorus present.

No. 3. Ironstone nodules above Beltiboy Coal.
(*a*) Metallic iron . . . . . 32·50 per cent.
Neither sulphur nor phosphorus.
(*b*) Metallic iron . . . . . 21·70 per cent.
No sulphur; a trace of phosphorus.
(*c*) (?) Black Band Ironstones.
Metallic iron . . . . . 23·50 per cent.
No sulphur; a trace of phosphorus.

No. 4. Iron nodules from Derry Coal.
Metallic iron . . . . . . 28·80 per cent.
No sulphur; no phosphorus.

Ironstone of the Antrim Coal-field.—This coal-field contains an important measure of Black Band raised in notable quantities and exported to Scotland in the calcined state. "The ironstone occurs in the lower beds of the carboniferous series. These beds consist of red and yellow sandstones, sometimes coarse, with beds of shale, the base of the series being a quartzose conglomerate reposing upon contorted mica-schist with veins of quartz." ‡ Analyses of the Ballycastle Black Band is not at hand; the composition, however, of one or two varieties raised extensively in Lanarkshire will show the constituents of these ores. The average yield of the Black Bands of the Clyde district may be taken at 31·60 per cent. in the raw, and 45·80 per cent. in the calcined state; Mushet's Black Band giving in the raw state 41·00 per cent. of metallic iron, increased to 63·10 per cent. in the calcined state :— §

* "Proceedings of the Royal Irish Academy," Second series, vol. ii., p. 537.
† The term "Shining Seam," is usually applied to "Micaceous Iron Ore."
‡ "Coal-fields of Great Britain," 4th edition, p. 339.
§ "Industrial Resources of Ireland," 1845, 2nd edition, p. 27.

Constituents.	Cross Basket Ironstone.	Mushet's Black Band.
Protoxide of iron	42·15	53·03
Lime	4·93	3·33
Magnesia	4·80	1·77
Silica	9·73	1·40
Alumina	3·77	0·63
Bituminous matter . . .	3·12	3·03
Carbonic acid	31·50	35·17
Moisture and loss . . .	...	1·41
Peroxide of iron	...	0·23
Total	100·00	100·00

Ireland, Southern Districts.—Ironstones of the Leinster Coal-field.—The ironstones of this coal-field are fairly illustrated by the following description and analysis of ironstone raised from the Castlecomer Collieries of Mr. Wandesford:—* "The colour is dark grey when fresh, but becoming rust-coloured by long exposure to the air. The specific gravity is about 3·250. When ignited it loses 29 per cent. of its weight, and the residue is strongly attracted by the magnet." Two different specimens give the annexed results:—

Constituents.	First.	Second.
Protoxide of iron	51·08	48·03
Lime	·16	1·51
Magnesia.	1·05	4·24
Alumina	1·86	1·45
Insoluble matter	13·92	16·17
Carbonic acid	31·93	28·60
Total	100·00	100·00
Metallic iron	39·70	37·60

It is remarked of these ironstones that as they were not selected for analysis on account of any apparent superiority to other specimens, they may probably represent the ordinary run of the ironstone of the Leinster district.

Iron Ore Deposits of the County Antrim.—The most important deposits of iron ore in Ireland now in process of development are situated in the county Antrim. For an account of the area including these deposits we reproduce an interesting paper

* "Industrial Resources of Ireland," 1845, 2nd edition, p. 132.

by Mr. J. D. Kendall, C.E., F.G.S., on the "Iron Ores of Antrim:—*

"The north-east corner of Ireland, that occupied by the county Antrim, is almost entirely covered by a sheet of basalt, varying in thickness from a few feet to upwards of a thousand feet. This basalt rests upon chalk, and is supposed, from the nature of the fossil plants yielded by it, to be of Miocene age. The following generalised section of the rocks in the county of Antrim will show its relative position in the geological scale:—

SYSTEM.	CHARACTER OF ROCK.
Tertiary	Basalt.
Cretaceous	Chalk. Greensand.
Oolitic	Wanting.
Jurassic	Lower lias shales.
Triassic	Variegated marls, &c. (Keuper). Sandstone (Bunter).
Permian (?)	Magnesian limestone, &c.
Carboniferous	Coal measures. Carboniferous limestone. Carboniferous slates.
Devonian	Red sandstone and conglomerate.
Silurian	Wanting.
Cambrian	Mica slate.

"Generally, the basalt may be divided into three classes—the amorphous, the columnar, and the concretionary—the second of which is well known to all who have visited the Giant's Causeway, on the north coast. The amorphous and concretionary varieties may also there be seen, between and below the tiers of columns.

"Although the basalt is not a sedimentary rock, yet it shows evident traces of bedding, as will have been noticed by all who have been along the Causeway coast. The basalt there exhibits two fine parallel tiers of columns, which have a gentle inclination inland. The lower tier, as it crops out at one point, forms the celebrated Giant's Causeway. Between and below the columns, the basalt has quite a bedded appearance, the beds being parallel to those exhibiting the columnar structure, that is dipping inland.

"**Mode in which the Ores occur and their Nature.**—Interstratified with the basalt, and parallel to the bed planes thereof, are a number of ferruginous clayey bands, of reddish appearance, which may be distinctly seen along the coast cliffs, presenting a

* "Colliery Guardian," 27th October, 1876, p. 657.

striking contrast to the basalt. The precise number of these bands is not known, but there are as many as five in some parts of the field, and there may be more. They occur one above the other, like seams of coal, at variable distances apart. Usually they consist of a ferruginous clay, called "bole," with an underlying layer of lithomarge. But there is one of the seams, which, in addition to these two materials, contains, above the bole, a thin band of iron ore, of a pisolitic nature. This is the most important band in the series. From it is obtained that ore of iron, which passes by the name of Irish ore. It occurs below the bottom tier of columns, and appears to be the highest of the series of ferruginous bands. It may be seen in the cliffs near the Giant's Causeway, and is found nearly all over the county. The following section of it will explain its nature, and show the relation it has to the basalt above and below it:—

ROOF OF SEAM.
Columnar basalt.—Lower tier.
Clay.—Slate coloured, passing imperceptibly into the overlying basalt. Its thickness is very irregular, and it peels off the basalt in laminæ parallel to the sinuosities of the under surface thereof.

"**Pisolitic Bed.**—This bed, which varies in thickness from a few inches to between 2 and 3 feet, consists of a soft, brown, or reddish-brown ferruginous ochre, in which are thickly embedded small dark grey irregular pieces of harder ore, which are strongly attracted by the magnet. The junction between this bed and the overlying clay is very distinct, and they separate easily. Pieces of fossil (coniferous) wood have been found in it, the tissue replaced by iron ore.

"**Bole.**—A yellowish-red ferruginous ochre containing a number of concretionary nodules of basalt. Not hard, and breaking up into irregular cuboidal pieces. The junction between this rock and the overlying ore is not very distinct. Thickness, usually 5 to 10 feet.

"**Lithomarge.**—A variegated soft rock of a prevailing blue slate colour. Like the bole, it contains concretionary nodules of basalt, but more of them. The line separating this bed from the bole is not very distinct. Sometimes this bed is nearly 80 feet thick:—

SOLE OF SEAM.
Concretionary basalt passes gradually into the overlying lithomarge.

"The extent of the pisolitic bed is not known, but it must cover some thousands of acres, although it does not occur everywhere within the basaltic area. In many places it has been removed by denudation, being found in the hills, but absent in the intervening valleys. The breach of continuity thus brought about is further increased by the numerous faults and dislocations that traverse the country.

"It is possible that there may be more than one pisolitic bed, that the seams which have been worked by the different mining companies in the county may not be portions of one original seam as is generally supposed, but may belong to different seams. So far, however, as is at present known, they appear to be parts of the same seam.

"The quality of the pisolitic ore is very good, as shown by the following analyses of ore worked at Red Bay by the Glenariff Iron Ore and Harbour Co., at Cargan and Broughshane by the Antrim Iron Ore Co., and at Slievan-anee by Messrs. Fisher and Co.:—

ANALYSES OF PISOLITIC ORE.

Constituents.	RedBay.	Red Bay.	Cargan.	Brough-shane.	Knock-boy.	Slievan-anee.	Slievan-anee.
Peroxide of iron	59·40	77·22	66·56	65·42	63·70	71·00	81·50
Protoxide of iron	..	..	..	..	..	18·00	..
Oxide of manganese	..	..	0·11	trace	..	trace	2·57
Titanic acid	..	trace	3·68	5·28	4·60	..	trace
Vanadic acid			..	..	..		
Alumina	2·80	..	7·92	12·54	12·75	..	4·20
Silica	10·40	20·65	5·47	7·08	6·30	9·00	8·50
Sulphur	..	..	0·03	trace	0·02	..	..
Phosphorus	..	..	trace	0·02	0·06	..	..
Magnesia	..	..	0·16	0·08	0·05	..	..
Lime	..	..	0·68	0·20	0·10	..	0·93
Water of combination	8·40	2·13	14·34	8·82	12·70	..	1·96
Per-centage of metallic iron	41·58	54·05	46·61	45·99	44·60	63·70	65·20
Analyst	Apjohn.	Cameron.	Tosh.	Tosh.	Tosh.	Cameron.	Hodges.

"The average amount of metallic iron contained in the above seven varieties of pisolitic ore is equivalent to 51·70 per cent., compared with 28·85, the average of the four following analyses of bole.

"The bole as a rule yields less than half as much iron as the pisolitic ore. The following are analyses of samples taken chiefly from the bole, but having a slight admixture of the pisolitic ore. The yield of iron is consequently higher than could be obtained from an unmixed sample of bole:—

ANALYSES OF BOLE.

Constituents.	Kilwaughter.		Glenarm.	Tully.
Peroxide of iron . . .	41·00	45·00	33·34	45·50
Oxide of manganese . .	...	trace	...	trace
Titanic acid	0·50		5·31	2·00
Alumina	51·00	36·44	41·13	35·50
Silica	1·00		3·78	4·00
Magnesia	trace	2·44	0·97	...
Lime	0·50	0·56	0·21	0·35
Sulphur	...	...	trace	...
Phosphorus	...	...	0·04	...
Water of combination .	6·00	18·00	15·55	12·65
Total . . .	100·	102·44	100·33	100·
Metallic iron . . .	28·70	31·50	23·34	31·85
Analyst	Cameron.	Cameron.	Tosh.	Cameron.

"The main difference between the pisolitic ore and the bole is, according to these analyses, in the greater quantity of iron and less quantity of alumina contained by the former. The yield of iron by the lithomarge is too small to render it of any value for iron making.

"**Origin of the Deposits: Lithomarge and Bole.**—The way in which the bole and lithomarge have been produced seems to be rendered very clear by the presence of the concretionary nodules. The graduation from bole to basalt, and from lithomarge to basalt, in the two sets of nodules, leaves no doubt that both these beds are the result of metamorphic action on basalt.

"The appearance presented by these nodules cannot possibly be explained on any other assumption than that both bole and lithomarge are metamorphosed basalt. But whether the rock from which they were produced, was exactly alike in chemical constitution to the basalt now above and below them, it is impossible at present to say, as, indeed, it is also to say whether they both have been produced from the same sort of rock, or from two chemically different rocks. The probability is that they were formed from beds of rock chemically different. If not, and they were both subjected to the same sort of metamorphism, then the two beds must represent two different stages of the process. But if bole be metamorphosed lithomarge, that is, if it has undergone a higher degree of metamorphism than lithomarge, we should

find in the concretionary nodules of the bole a transition from basalt to lithomarge in the first place, and then from lithomarge to bole; in other words, between the bole and basalt we ought to find a layer of lithomarge, but we do not—at least I have not. Then again if lithomarge is altered bole, we should find in the concretions of the lithomarge bed a layer of bole immediately round the basalt, which we do not. This inclines me to the idea that the bole has been produced from a bed of rock (basalt) having a different composition from that which has been altered to lithomarge. A fact which may throw some light on the mode of metamorphism may be observed in connection with the bed of clay lying between the pisolitic bed and the overlying basalt. This clay, I believe, is also metamorphosed basalt, for there is a most gradual laminated passage from hard basalt to soft clay.

"The fact I refer to is that whenever the clay bed crops out to day it appears to thicken, which seems to indicate that whatever was the metamorphic influence, it acted more powerfully than at any other point.

"**Pisolitic Bed.**—This bed has been variously accounted for; some have supposed it to be of igneous origin, others consider that it is metamorphosed bole, whilst not a few are of opinion that it had an aqueous origin. The fact already pointed out that fossil wood has been found in the bed seems to favour the last idea. It clearly precludes the possibility of the first and second. Besides if this ore is the result of metamorphic action on the bole, why do we not find the same sort of ore accompanying the other bole beds? They were all alike overlaid by a bed of basalt, which, according to the holders of this theory, had a considerable influence in altering the bole into ore.

"The precise mode of deposition usually advocated by those who believe in the aqueous origin of this bed, is the sedimentary. But that, I think, is scarcely reconcileable with the facts. The freedom of the ore from the mechanical admixture of other rocks seems to me alone a sufficient argument against any theory which would account for its deposition in that way.

"The most likely mode of origin appears to be that of precipitation from a chemical solution, possibly by organic agency, but not necessarily so. On that supposition the absence of foreign matter, such as would almost assuredly have been present had the bed been of sedimentary origin, offers no difficulty, whilst the occurrence of

the wood is as easily explained as by the sedimentary theory. And if we suppose that the bed of rock (basalt) from which the bole was produced was in a comparatively soft and decomposed state, at the time the ore was deposited, we have a probable explanation of the fact, already stated, that the junction between the ore and bole is not very distinct. Some of the first precipitated ore would almost certainly find its way into the decomposed bed below, the effect of which would be to produce the appearance of a regular transition from iron ore to bole. The pisolitic condition of the ore is probably due to the influence of the overlying lava whilst in a heated condition.

"**Working the Deposits.**—The geographical conformation of the area covered by the basalt is such as to render the working of the iron deposits a matter of great simplicity. The seam (assuming that there is only one) is usually found cropping out on the hill sides and lying nearly level. It is in consequence worked by day levels. No shafts are required, nor any pumping machinery, the water being carried off by the levels. The ore is soft and easily worked, whilst the roof is strong and good, so that very little timber is required. All that is used is obtained from the immediate neighbourhood at a very low price. In addition to all these advantages wages are low; so that the working expenses of a mine are very light. The greatest drawback to the working of these mines is their distance from port, some of them being so far away that the ore costs 3*s*. or 4*s*. or more per ton for carriage. In some cases, too, the pisolitic ore is not more than a foot in thickness, so that a portion of the bole has to be worked away with it, and it is only in good times that much of this bole can be sold, so that the necessity to work it whether it can be sold or not, increases, as a consequence, the cost of getting the pisolitic ore. But for these two circumstances Irish ore would occupy a much more important position in our market than it does."

The area of the county Antrim occupying the ferruginous deposits extends on the north-east coast from Cushendall to Carrickfergus, and inland from two to ten miles. From this area for some years past the mines have furnished the great bulk of the iron ore raised in Ireland.

At Evishacrow, between Ballymena and Cushendall, in the county Antrim, hematitic iron ore is wrought in some quantities. A section of strata at these mines presents the following stratified

beds: at the surface appears basaltic rock reposing upon a seam of iron ore known as pisolitic or "shot ore," and having an average thickness of some 18 inches; this ore consists of nodules of almost pure oxide of iron, varying in size from the head of a pin to a small nutmeg, and embedded in a soft ochreous matrix or paste. Locally it has received the appropriate name of shot ore. Next in descending order occurs a bed of aluminous ore, varying in thickness from 4 to 6 feet, and containing 22 per cent. of metallic iron; this is advantageously employed in the blast furnace as a flux. Beneath the aluminous ore occurs a deposit of blue lithomarge found in thickness varying from 25 to 35 feet.

The ferruginous deposits of the Evishacrow mines occur at an elevation of 870 feet above the level of the sea, the strata dipping gently to the south-west.

The mode of working these mines, like others in the district, is by driftways driven in from the mountain side at the outcrop of the deposit. The headings are pushed forward to the north-east, following the rise of the pisolitic deposit, which affords a gentle incline to the mouth of the workings, thus facilitating the running out of the loaded corves. This inclination also allows the mine waters to get away easily by gravitation, a very effective natural drainage being thus formed. The roof of the mine is self-supporting, no timbering being used in the workings beyond the first 13 fathoms or so in each of the drifts. The mode of working is the long wall system, the ore is easily won, and does not require blasting, being brought away easily with the pick; it is of singular purity, having no trace of either sulphur or phosphorus. This class of ore is extensively used in steel making. The mines are connected by a branch with the Ballymena, Cushendall, and Red Bay Railway, which enables the ore to be sent either to Belfast or Larne for shipment, from which latter port considerable quantities are shipped, the port having been lately greatly improved, and recently connected with the Ballymena and Larne Railway.

The royalty under which the workings at Evishacrow are carried out covers an area of 800 acres, and it is estimated that iron ore exists under the greater part of this area. Dr. Percy, to whom samples of the ore was submitted, gives the following analysis, showing its composition per cent.:—

RESULTS TABULATED.

Peroxide of iron	75·51
Protoxide of iron	2·92
Protoxide of manganese	0·24
Lime	traces
Magnesia	traces
Alumina	3·14
Silica	5·54
Titanic acid	9·50
Combined water	2·00
Hygroscopic water	1·32
Phosphorus	none
Sulphur	none
Total	100·17
Metallic iron, per cent.	55·13

Dr. Percy adds, " The ore is *remarkably* free from phosphorus and sulphur, and will yield pig iron very suitable for conversion into steel by the Bessemer process. The presence of titanic acid will not injuriously affect the quality of the pig iron, for some of the best Swedish bar iron is made from ore rich in titanic acid. The ore may be regarded as rich, and in that respect is equal to the average of the red hematites."

The mines of the Antrim Iron Ore Company, situated at Broughshane, Cargan, Carnlough, Glenarm, and Newton Crommellin, are of considerable extent, and yield large returns. The pisolitic ore here wrought is found, as in the districts previously referred to, in beds varying from 15 to 24 inches in thickness, and beneath basaltic rock which reposes upon it. A bed of aluminous ore occurs below the pisolitic ore, but it is only worked to a limited extent from the circumstance of its being less rich in metallic iron than the pisolitic ore. Lithomarge is also met with of a prevailing blue colour, in a bed of considerable thickness, and, like the aluminous ore, it is not extensively worked, as it is too poor in metallic iron to render it of value for iron making. The deposits in the above-named localities lie some 600 or 700 feet above the level of the sea.

The constituents of these ores, rich in alumina, varying from 30·00 to 34·55 per cent., from the mines of Glenarm and Carnlough, are as follows:—*

* Favoured by Silas Evans, Esq., of Belfast.

Constituents.	Glenarm.	Carnlough.	Carnlough.
Peroxide of iron	50·23	29·88	24·75
Protoxide of iron	1·03	1·99	0·72
Protoxide of manganese	0·44	0·24	0·35
Alumina	30·00	33·69	34·55
Lime	0·29	0·92	0·77
Magnesia	0·26	0·16	0·27
Silica	9·50	11·58	5·10
Titanic acid	0·70	0·74	1·15
Sulphuric acid	...	trace	...
Phosphoric acid	...	...	...
Water { hygroscopic	2·51	21·65	32·48
Water { combined	5·13		
Total	100·09	100·85	100·14
Metallic iron	35·96	22·47	17·89
Analyst	Heywood.	Tosh.	Tosh.

Mr. Charles A. Heywood, public analyst of Whitehaven, who examined the Glenarm ore, remarks of it, "That it contains a high per-centage of metallic iron, some manganese, and no sulphuric or phosphoric acids. It is of great use on account of its containing an excess of alumina, as a flux in the blast furnaces using siliceous red hematites. The per-centage of water is very small, the ore is hard, and will bear a heavy burden in the furnace."

The deposits worked at the Glenariff mines situated near Cloughor, in the county Antrim, by the Glenariff Iron Ore and Harbour Company, Limited, are thus described by Mr. Philip Argall, captain of the mines: "The iron ore measures of the Glenariff valley are found interstratified with igneous rocks (dolerites, basalts, and tuffs) of tertiary age."

At the mines now working the iron ore the measures are about 70 feet thick, and are found to rest on about 400 feet of dolerite, being covered by about 300 feet of a similar rock; these measures or ores may be divided into four classes as follows: "Lithomarge," * "Pavement," Aluminous Ore (Ball or Second Ore), and Pisolitic Hematite or First Ore.

The lithomarge varies from 40 to 45 feet thick, and contains from 15 to 20 per cent. of metallic iron, and 30 per cent. of

* "Lithomarge." A silicate of Alumina. In many respects resembling Kaolin, or China clay. In this instance it appears to bear a local signification.

alumina; it varies in colour from light lavender to black, and is often liver coloured, or bluish with white spots.

Analysis of the lithomarge above referred to is not available. A continental variety, however, rich in alumina, will show its general composition.*

CONSTITUENTS.

Silica	49·20
Alumina	36·20
Peroxide of iron	0·50
Water	14·00
Total	99·90

Resting on the lithomarge is a yellowish ochreous rock, called "pavement" by the miners, as it forms the floor or pavement of the first and second ores; this rock varies in thickness from 15 to 20 feet, and contains from 20 to 25 per cent. of metallic iron, and about 30 per cent. of alumina.

The aluminous ore (second ore) is generally found resting on the "pavement," but it frequently occurs in beds of from 4 to 5 feet in thickness, interstratified with the lithomarge and pavement. The aluminous ore is of a light red colour, and is brittle though soft, and contains from 25 to 30 per cent. of metallic iron, and from 35 to 40 per cent. of alumina; this ore is sometimes called *bauxite:* where it occurs immediately under the pisolitic ore it usually has a few pisolites of the former disseminated through it.

Overlying the aluminous ore, or where it is absent, is found the pisolitic, or first ore; this is covered by the hard dolerite roof, and separated from it by a few inches of steatitic clay.

The pisolitic ore varies from 12 to 20 inches, and sometimes swells from 24 to 30 inches in thickness, and is usually found best developed at the top of the seam which is the richest part. The ore is also found to vary in colour from red through brown to black, the latter being most abundant at the Glenariff mines. The black ores usually contain from eight to ten per cent. of titanic acid, and are regarded as the richest and purest to be found in the county. The first two ores, examined by Mr. E. W. J. Jones, public analyst of Wolverhampton, give the following results:—the first a pisolitic ore, the second an aluminous ore.†

* "Glossary of Mineralogy." H. W. Bristow, F.R.S., p. 221.

† Favoured by John Ham, Esq., Secretary of the Glenariff Iron Ore and Harbour Company, Limited.

The third analysis of best Glenariff ore is by Mr. A. B. Cowan.

RESULTS TABULATED.

Constituents.	First.	Second.	Best Ore.
Combined water	...	10·23	1·88
Peroxide of iron	71·64	35·93	62·43
Protoxide of iron	1·88	trace	4·75
Protoxide of manganese . .	0·27	0·11	0·28
Alumina	4·25	36·50	10·19
Silica	5·05	12·20	8·40
Lime	0·81	0·53	2·80
Magnesia	0·61	1·41	0·59
Phosphoric acid	0·20	trace	nil
Sulphuric acid	nil	nil	nil
Carbonic acid	trace	nil	trace
Pyrites	nil	nil	...
Titanic acid	8·89	nil	...
Moisture at 100 C.	6·40	2·76	8·48
Loss, &c.	...	0·33	...
	100·00	100·00	99·80
Metallic iron per cent. . .	...	25·15	47·40

The iron ore and "bauxite" deposits worked by the Irish Hill Mining Company at their Irish Hill and Straid Mines, situated near Ballyclare, possess some interesting features; they were discovered some 5 or 6 years since by Mr. Alexander Sutherland.* The bauxite is believed to be the largest deposit of that ore hitherto discovered in this country. The rocks of the surrounding district are basalt, trap, and porphyry. The iron ore exists in conformable strata, not unfrequently with very little rise or dip, and the best qualities are found close to the basalt which forms the roof of the level drifts and workings in the above-named mines. The strata containing the iron ore is divided into three distinct layers or seams; the first, nearest the roof or base of the basalt, is from 1 to 2 feet 6 inches thick of pisolitic ore, containing 60 per cent. of peroxide of iron. The second seam beneath the first, is 3 feet thick, and contains 40 per cent. of peroxide; the third or lowest seam in the series is lithomarge, which is often 20 feet deep, containing at its top (or junction with the base of the second) from 20 to 30 per cent. of peroxide of iron, which, however, is found to gradually diminish in percentage towards the bottom of the seam.

* Who has kindly furnished the following description and analyses of the iron ore and bauxite deposits.

The lithological characteristics of these ores are thus referred to :—First ore, rich red coloured, often purple, in which are embedded nodules of peroxide and magnetic oxide of iron, varying in size from a pin's head to that of a hazel nut; the smaller nodules when rubbed with a file are said to present the same appearance as cast-iron under the same process. In some cases the upper seam is dark brown in colour, especially when disturbed by basaltic or trap dykes, which are frequently met with. The ore is then found to consist of loosely aggregated particles, having a bright metallic lustre, the nodules being invariably small and highly magnetic.

The second seam also possesses a considerable quantity of nodules; these, however, are poor in iron, and often so soft as to be easily cut with a knife, the surrounding ore or matrix being much lighter and softer than the first or upper seam.

The third or lithomarge seam never contains any nodules, is homogeneous throughout, for the greater part of its depth; it is of a fine brick-red colour, easily cut with a knife, friable, breaking into small pieces on exposure to the air; near its base, however, it becomes lighter in colour, ultimately changing to a purple, and often presenting a very beautiful appearance, the purple being often speckled with small red and white coloured spots.

Analysis of the ore of the first and second seams, made by Mr. John Pattinson of Newcastle-on-Tyne, gives the following results :—

ANALYSIS MADE ON SAMPLE DRIED AT 212° FAHR.

Constituents.	First Ore.	Second Ore.
Peroxide of iron	53·50	41·85
Protoxide of iron	0·70	0·25
Protoxide of manganese	trace	trace
Alumina	18·67	31·10
Lime	0·48	2·55
Magnesia	0·58	0·48
Titanic acid	4·00	3·60
Silica	11·80	9·67
Sulphur	nil	0·03
Phosphoric acid	trace	trace
Combined water	5·50	10·37
Moisture	5·10	...
	100·33	99·90
Metallic iron	38·00	29·50

These ores have been employed in the works of the Ditton Brook Iron Co. Limited, near Warrington, with very satisfactory results, in making, in admixture with other ores, the higher classes of pig iron for Bessemer steel making.

The bauxite deposits worked at Irish Hill are found taking exactly the place of the first or pisolitic iron ore seam previously referred to, and like it, also, having basalt overlying it. What has been said as to the disposition of the iron ore, is true also regarding that of the bauxite, except that the order is entirely reversed, the best bauxite, *i.e.*, containing the least amount of iron, is found on the top of the strata, or at the base of the basalt, and the greatest amount of iron exists at the bottom of the strata, in fact the iron gradually increases in depth.

The total depth of the bauxite strata has not hitherto been ascertained. The best, or that containing under 1 per cent. of iron, may be represented as averaging some 3 feet thick, indeed, it is never under 2 feet, and often varies from 5 to 6 feet thick; beneath this is the second quality containing from 4 to 5 per cent. of iron; the third or lowest containing from 12 to 15 per cent. of iron, with about the same percentage of titanic acid. It is stated that the bauxite is most compact next the roof, and is occasionally found fractured into innumerable cubes.

The only division existing between the bauxite and the basalt is a thin seam, varying from a film to 2 or 3 inches, and composed chiefly of decomposed basalt, and sometimes organic matter similar to lignite, but much softer. Mr. Sutherland, in conclusion, adds, "that it must be borne in mind that the basalt in juxtaposition shows no symptoms of deterioration. There is a decided parting between the first and second and also the third seams. No substance intervenes to effect this parting, which is somewhat similar to that existing in limestones, but not so clearly delineated as in limestone partings." The bauxite deposits are invariably associated with lignite, and in some cases lignite occurs above and below. The lignite often exists in seams, and exhibits very distinct parallel, polished striæ, or slickensides; which is most interesting, as they denote the movements by disturbance to which the locality has been affected.

The three varieties of bauxite above referred to, have been examined by Mr. John Pattison, of Newcastle-on-Tyne, with the following results:—

ANALYSES OF THE SAMPLES DRIED AT 212° FAHR.

Constituents.	First quality.	Second quality.	Third quality.
Alumina	53·83	52·00	46·13
Peroxide of iron	1·57	4·57	15·14
Lime	0·62	0·79	0·18
Magnesia	0·13	0·20	0·26
Potash	0·01	0·02	0·04
Soda	none	0·06	0·24
Silica	8·67	12·00	10·40
Titanic acid	5·80	6·20	4·20
Sulphuric acid	0·07	0·07	0·10
Phosphoric acid	trace	trace	trace
Combined water	29·27	24·00	23·39
	99·97	99·91	100·08

The amounts of moisture lost by drying at 212° Fahr. were as follows :—

First quality	7·50 per cent.
Second quality	0·90 ,,
Third quality	0·85 ,,

The following is the composition of the three samples in the condition in which they were received :—

Constituents.	First quality.	Second quality.	Third quality.
Alumina	49·80	51·53	45·74
Peroxide of iron	1·45	4·53	15·01
Lime	0·57	0·78	0·18
Magnesia	0·12	0·20	0·26
Potash	0·01	0·02	0·04
Soda	none	0·06	0·24
Silica	8·02	11·89	10·31
Titanic acid	5·37	6·14	4·16
Sulphuric acid	0·06	0·07	0·10
Phosphoric acid	trace	trace	trace
Combined water	27·07	23·79	23·19
Moisture	7·50	0·90	0·85
	99·97	99·91	100·08

Iron Ore Deposits of the County Wicklow.—Deposits of iron ore have been recently wrought to some extent at Kilbride, in the county Wicklow, of the variety known as magnetic oxide. Mr. Tichborne has examined these deposits, and in a paper read before the Royal Geological Society of Ireland, in November, 1876,

he describes the ore "as forming a vein certainly two miles, and, according to indications, three miles long; with a width varying to 6 feet in some parts, and a supply reported to be very extensive. Specimens of the ore from the surface submitted for examination were a loose friable sand, more or less spongy, but perfectly free from organic remains. As the vein was pursued in a vertical direction, it became more compact, until a dense ore with a specific gravity of 4·37 was arrived at. The silica, which in large quantities made magnetic ore useless for smelting, is extremely low in this ore." Iron ore also occurs, and is wrought in this county at the Cronebane and Ballymurtagh mines.

Iron Ore Deposits of the Counties of Longford and Cavan.—Professor Hull, F.R.S., gives the following interesting particulars respecting the hematitic ores of the counties of Longford and Cavan. "The lower silurian rocks were known for some years past to have possessed such ores, but until railways communicating with shipping ports were constructed there was little prospect of these ores being turned to profitable account. This obstacle has been overcome, and the hematite ores are now sent by the Midland and North-Western lines to Dublin and Dundalk, where they are shipped to the iron furnaces of the north of England and Wales. These ores are known to exist in at least four localities, three of which lie in the district between Granard and Carrick on Shannon, and another in the district between Cavan and Ballybay."

Another district examined by Professor Hull at Red Hills, in the neighbourhood of Belturbet, in the county Cavan, is now in process of development. Here the ore has been traced at intervals in a S.W. and N.E. direction for a distance of about six miles, following the strike of the silurian rocks from Ballyhaise through Red Hills to the grounds of Scott's house, the residence of Mr. Madden. Whether it is perfectly continuous throughout this distance is uncertain, as the strata are frequently concealed by boulder clay, but in any case the quantity of ore must be very large. On the property of the Rev. E. B. Whyte Venables at Red Hills the ore is wrought and conveyed by canal and rail to the port of Dundalk, where it is shipped to Lancashire, Cumberland, and North Wales.

The hill on which the principal excavations are in progress shows the following approximate section of the strata:—

1. *At the top.*—Siliceous hematite, sometimes passing into green jasper (only locally workable) 2. *Best Ore.*—Dark fissile brown hematite about 12 feet in thickness . . . . 3. *Inferior quality.*—Siliceous brown hematite, irregularly accumulated, passing into jaspery rock	About 50 feet in thickness.
4. *Reddish shales* of considerable thickness, sunk through in a pit for 80 feet	65 feet.

In appearance the ore when opened out seems almost devoid of definite arrangement or structure, and it is only when in contact with beds of shale or grit that it can be observed to coincide approximately with the bedding of the rock. It therefore does not occur in a lode or vein traversing the strata in a highly inclined position, but rather in the form of lenticular beds of extreme irregularity; the ore itself is split up by innumerable planes of jointage, or false cleavage, traversing the mass in various directions.

An analysis of the Red Hills ore by Mr. John Cameron, F.C.S., of Askham-in-Furness, for the Red Hills Mining Company, shows that the ore is well suited for the manufacture of Bessemer steel, phosphorus and sulphur being entirely absent:—

ANALYSIS OF RED HILLS IRON ORE.

Peroxide of iron	57·57
Peroxide of manganese	traces
Protoxide	6·20
Alumina	8·93
Carbonate of lime	0·50
Silica	22·80
Water of combination	3·00
Soluble matter	1·00
Total	100·00

Amount of metallic iron 40·30 per cent.

Ireland: Production of Iron Ore.—Brown hematite has been raised in considerable quantity in the county Wicklow at the Ballymurtagh and Cronebane mines, where also copper ore and pyrites are obtained. In the former mine the iron ore is found occurring in the North Pyrites lode. This lode is composed of iron ore to a depth of some 16 fathoms from the surface, when it passes into the ordinary pyrites of the neighbourhood. Iron ore was first raised about the year 1856, but the earliest return

met with is for the year 1863, since which year iron ore has been sold in the following quantities, giving an average price of 12*s.* per ton at port of shipment, the ore yielding of metallic iron from 46 to 50 per cent.:—

BALLYMURTAGH IRON ORE.

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1863	6,286	2,200	1872	9,978	8,890
1864	25,816	7,744	1873	...*	...
1865	5,136	1,798	1874	16,433	16,411
1866	4,850	1,455	1875	6,663	3,331
1867	5,500	1,512	1876	56	29
1868	12,500	2,968	1877	2,778	1,529
1869	7,000	1,750	1878	1,100	610
1870	8,250	2,062	1879	100	65
1871	9,860	4,930	1880	4,002	2,502

At Cronebane the brown hematite or limonite is found occurring as a gossan on the backs of the mineral veins, and is generally found near the surface, continuing in depth about 8 fathoms. The greatest depth at which it has been reached is 25 fathoms, its breadth varying from a few inches (where the vein is filled with flookan, more or less impregnated with oxide of iron) to 6 fathoms, and would average about two fathoms. The gossan rests upon decomposed clay slate and pyrites, which becomes firmer and harder in depth, and in which black oxide of copper occurs disseminated throughout the mass in every direction.

The quantities and value of iron ore produced in each year since 1872 are as follows:—

Year.	Quantities.	Value.
	Tons.	£
1872	2,155	1,239
1873	4,143	2,485
1874	27	21
1875	1,324	662

The character of the Cronebane ore will appear in its average value per ton, which at the port of shipment in 1873 was 12*s.*, receding to 10*s.* in the year 1875, since which date the working of the iron ore has been in abeyance.

* No return.

Before proceeding to summarise the total output of iron ore raised from the mines in Ireland, which is steadily increasing, it will afford some interest to note in detail the quantities and values of the ores of a few of the more important mines, which are as follows:—

ANTRIM IRON ORE COMPANY'S MINES.

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1871	37,000	16,650	1876	30,812	13,865
1872	40,048	20,024	1877	40,835	24,659
1873	38,522	19,261	1878	50,700	26,957
1874	37,719	33,947	1879	54,193	26,316
1875	29,060	21,975	1880	68,660	31,038

In the year 1871 the average price of these ores was 9*s*. per ton; four years later 18*s*. per ton was realised, since which date prices have diminished, till in 1879 the average was 10*s*. per ton, F. O. B. at port of shipment, and in 1880 of the above quantity 52,000 sold at 10*s*. per ton, the remainder at 6*s*. per ton.

The Glenravel mines, situated at Slieve-an-nee, also in the county Antrim, and worked by Messrs. John Fisher & Co., produced ore in the following quantities and value in each year since 1870:—

GLENRAVEL MINES.

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1870	15,000	...	1876	14,403	7,921
1871	20,000	18,000	1877	18,367	10,102
1872	23,605	21,243	1878	16,770	8,385
1873	24,699	22,158	1879	15,961	7,980
1874	21,791	19,611	1880	43,043	10,761
1875	16,896	12,516			

The Newton Crommelin Mines, producing brown hematite, the Irish Hill and Straid Mines bauxite, and the Island Magee Mines bole and lithomarge, the latter belonging to the Irish Hill Mining Co., produced ore in the following quantities and value in each year since 1870:—

Year.	Newton Crommelin.	Irish Hill, Bauxite.	Island Magee.
	Tons.	Tons.	Tons.
1873	5,815	...	...
1874	...	2,000	6,450
1875	...	...	1,200
1876	6,786	594	9,000
1877	26,842	2,763	...
1878	32,142	3,426	3,683
1879	30,715	3,657	2,845
1880	22,500	2,470	4,403

In the last-named year the Newton Crommelin ore averaged 10*s*. 6*d*. per ton; bauxite, 20*s*. per ton; and the Island Magee ores 10*s*. per ton at port of shipment.

Of the iron ore produced in the county Antrim the great bulk is exported from Belfast, the remainder from neighbouring ports on the coast. The quantities shipped from Belfast were as follows in each of the years named, a great increase appearing in the exports of 1880 over previous years:—

Year.	Tons.	Year.	Tons.
1870	24,835	1876	71,215
1871	14,408	1877	96,805
1872	22,254	1878	83,327
1873	9,768	1879	88,071
1874	33,108	1880	122,529

The black band ironstone raised at Ballycastle in the Antrim coal-field, with its value, in each year since 1858, appears as follows:—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1858	3,600	1,170	1869	26,746	6,686
1859	3,000	1,100	1870	25,000	6,250
1863	15,736	3,934	1871	14,409	8,644
1864	18,763	4,690	1872	30,000	27,000
1865	15,000	3,750	1873	24,835	22,351
1866	9,821	2,455	1875	300	150
1867	17,600	4,400	1876	431	237
1868	17,000	4,500	1878	4,375	1,187

The quantity raised in 1880 was 1,051 tons, of the value of £630 12*s*.

The ironstone is conveyed to Belfast where it is shipped to Scotland, and from the above returns it is clear that in years

when the iron trade is active the ironstone is in good demand, commanding a high price. In 1872 and 1873 the average price per ton reached 18*s*., since which date the production shows a falling off, also the price, which in 1880 gives an average of 12*s*. per ton.

In the annexed summary is given the production of iron ore of all varieties in Ireland since the year 1856, also its value, and the number of mines raising and selling ore in each of the same years:—

Year.	Number of Mines.	Iron Ore.	Value.
		Tons.	£
1856	1	441	...
1857	2	3,000	...
1858	1	3,600	1,170
1859	1	3,000	1,100
1860	3	107	43
1861	2	165	66
1862	4	10,431	6,038
1863	4	31,673	11,085
1864	4	60,602	20,326
1865	5	29,117	8,202
1866	5	25,525	5,314
1867	7	42,016	10,641
1868	5	41,469	10,492
1869	6	48,804	12,201
1870	8	77,600	19,405
1871	13	107,735	66,043
1872	18	176,500	158,562
1873	15	138,705	123,567
1874	21	140,360	112,089
1875	21	128,602	91,332
1876	20	116,010	60,748
1877	17	155,382	85,427
1878	16	156,834	74,809
1879	18	155,833	79,286
1880	21	239,325	112,812

The returns of production given above, more especially of late years, indicate clearly that as a flux these ores are becoming more and more appreciated by the ironmasters of Great Britain. The ores are exported largely to Cumberland, Lancashire, South Wales and Scotland, Staffordshire, and the Cleveland district. Since the year 1875, it will be seen that the production has increased nearly twofold. In the following statement is given the quantities used in the districts named (as far as returns have been received) in each year since 1875. The quantities fall far

short of the production of the iron mines of Ireland in each of the same years :—

Year.	Cumberland.	Lancashire.	South Wales.	Scotland.	Other Districts.
	Tons.	Tons.	Tons.	Tons.	Tons.
1875	21,119	28,460	14,757	11,500	52,766
1876	16,029	25,000	13,913	11,779	49,289
1877	17,487	39,804	19,436	12,212	66,443
1878	18,633	38,000	17,470	11,480	71,251
1879	20,791	38,460	19,800	10,961	65,821
1880	38,206	26,093	25,146	15,981	133,899

The production of the iron mines in the year 1880 are shown in the following table, with the values of the several varieties :—

IRELAND.

No.	County and Name of Mine.	Character of Ore.	Quantities.		Value.	
			Tons.	Cwts.	£	s.
	County Antrim.					
1	Aughalun (Carnlough) . .	Aluminous . .	413	0	144	11
2	Ballybaley	,, . .	3,170	0	1,109	10
3	Ballypalady	,, . .	11,446	0	4,006	2
4	Ballycastle	Black Band . .	1,016	0	630	12
5	Cargan and Parkmore (Ballymena)	Pisolitic . .	24,368	0	12,184	0
6	Cloughor and Glenariff . . .	,, . . .	15,862	0	7,931	0
7	Duneany (Glarryford) . .	Aluminous . .	5,668	0	2,834	0
8	Evishnably and Gortnagerah . .	,, . .	27,760	0	13,880	0
9	Evishacrow (Glenravel) . .	Brown Hematite.	12,500	0	4,687	10
10	Glenarm	Aluminous . .	16,459	0	4,937	14
11	Glenravel (Slieve-an-nee) . .	Brown Hematite.	43,043	4	21,526	12
12	Island Magee	Lithomarge . .	4,403	0	1,100	15
13	Irish Hill and Straid (Ballymena)	Bauxite . .	2,470	0	2,284	15
14	Knockboy	. . . . .	2,000	0	700	0
15	Main	Aluminous . .	5,391	0	2,695	11
16	Newton Crommelin . . .	Brown Hematite.	22,500	0	11,250	0
17	Orblereigh (Portrush) . . .	,, ,, .	4,795	0	2,397	10
18	Rathkenny and Broughshane (Ballymena)	Aluminous . .	27,833	0	13,916	10
		Total . .	231,132	4	108,216	12
	County Tyrone.					
1	Barrow (Cookstown) . . .	Brown Hematite.	572	0	286	0
	County Londonderry.					
1	Ballylaggin (Coleraine) . .	Aluminous . .	3,617	0	1,808	10
	County Wicklow.					
1	Ballymurtagh.	Brown Hematite.	4,002	0	2,501	5
	Total of Ireland . .		239,235	4	112,812	7

The mines producing iron ore or in course of development in Ireland in 1880 appear in the following list, with their situation, proprietor, or company, working the same, and the manager :—

No.	Name of Mine.	Situation.	Name of Proprietor or Company.	Name of Manager or Agent.
			ANTRIM.	
1	Aughalan . . .	Carnlough . .	Francis Ritchie and Sons	Robert M'Calmont.
2	Ballybaley . . .	" . .	" " "	" "
3	Ballymartin . .	" . .	" " "	" "
4	Ballylaggin . . .	Coleraine .	Benj. Townson . .	Thomas Simmons.
5	Cargan . . .	Ballymena .	Antrim Iron Ore Co., Lim.	Robert Browne, Sec.
6	Glenarm . . .	Glenarm . .	" " " .	" "
7	Rathkenny . .	Ballymena .	" " " .	" "
8	Glenariff . . .	Clogheor . .	Glenariff Iron Ore and Harbour Co., Lim. .	John Ham, Sec. Philip Argal.
9	Cloughor . . .	Ballymena .	" " "	" "
10	Ballycastle . . .	Ballymoney .	Godden and McDonald .	John James.
11	Drumnavaddy . .	Dunloys . .	Dunloys Iron Ore Co. .	Silas Evans.
12	Duneany . . .	Garryford . .	Wm. Boaden and Co. .	Peter Hanlon.
13	Elgenay . . .	Broughshane, Ballymena.	Knockboy Mining Co. .	Isaac Ross.
14	Evishnably . . .	Garryford . .	Mountcashel Iron Ore Co., Lim.; J. F. Rowbotham, Sec. .	Silas Evans.
15	Evishaerow . .	Glenravel .	Charles Chambers .	John Robertson. Wm. Edwards.
16	Irish Hill and Straid	Ballynure . .	Irish Mill Mining Co. .	Alexander Sutherland.
17	Glenravel . . .	Sleive-an-nee .	John Fisher and Co. . .	Hugh Raw.
18	Island Magee . .	Larne. . .	Francis Ritchie and Sons	Robert M'Calmont.
19	Ballypalady . .	" . .	" " "	" "
20	Knockboy . . .	Ballymena. .	Knockboy Mining Co. .	Isaac Ross.
21	Parkmore. . . .	" .	Parkmore Iron Ore Co. .	Alexander Gillespie.
22	Shanes and Agnews Hill . . .	Larne . .	The Larne Iron Mining Co.	Thomas Fisher, Engineer.
23	Orblereigh . .	Portrush .	Benjamin Townson . .	Thomas Simmonds.
24	Newton Crommelin .	Glenravel . .	S. D. Crommelin . .	James G. Carrick.
25	Maiden Mount. .	Carrickfergus.	M. Robert Dalway, M.P.	James Hodkinson.
26	Main	Portrush . .	Benjamin Townson. .	Thomas Simmons.
			DOWN.	
1	Deehomed . .	Ballynahinch.	County Down Iron Mining Co. . .	Jas. C. Greer.
			WICKLOW.	
1	Cronebane. . . .	Ovoca . .	Associated Irish Mines Co. . . .	Geo. Oates.
2	Ballymurtagh . .	" . .	The Wicklow Copper Mines Co. . .	John Hodge.
			TYRONE.	
1	Barrow . . .	Cookstown .	The Barrow, Hematite Co., Limited . .	William Kellett.

Manufacture of Pig Iron.—It appears from the "Geological and Mining Survey of the Connaught Coal-field" published in the year 1818,* that at an early period the number and richness of the beds of ironstone in the Connaught coal district attracted the attention of Irish speculators, resulting in the establishment of works on a small scale called bloomeries, carried on in various parts of the adjoining country as long as wood remained to supply them with charcoal. At the time referred to, no coal had been discovered, and if it had been, the process of making pig iron from pit coal was then, though partially known, not practised even in England.

* By Sir Richard Griffith.

The ironworks of Drumshambo were the last that continued to work; they were given up about the year 1765. These works were situated at the southern extremity of Lough Allen, in the county of Leitrim, a quarter of a mile west of the village of Drumshambo. The locality selected possessed much interest; the works were built upon a limestone rock, distant about a quarter of a mile from the coal country. The situation was particularly favourable for making iron at a cheap rate. The ironstone was chiefly collected from the eastern shore of Lough Allen, and in the beds of the precipitous streams which descend from the Slieve-a-Nierin mountains to the lake.

The appearance of trivial workings, made in search of the ironstone, are still visible along the borders of these streams. The ironstone when collected was conveyed by boats to the works, and charcoal from the vast woods which at one time flourished in all the valleys, was carried by the same means. Limestone, the only remaining ingredient for smelting iron, was quarried close to the works. Judging from the accounts given by the oldest inhabitants, and the remains still visible, the Drumshambo ironworks appear to have consisted of one blast furnace 3 feet square in the interior, and about 18 or 20 feet high. Large heaps of ironstone of excellent quality still remain at the works. It is much superior to that used at the more modern Arigna ironworks. The smelted iron from the Drumshambo works was carried to the neighbouring village, where it was forged into bars.

The Arigna ironworks were commenced about the year 1788 by three brothers of the name of O'Reilly. At that time the practicability of smelting iron with pit coal or coke instead of charcoal was well known and long practised in England and Scotland with great advantages to the adventurers. In the same year in which the Arigna works were commenced there were 53 blast furnaces in England and Wales, and 6 in Scotland, the annual produce amounting to 53,800 tons of pig iron.

The Arigna works, situated on the west side of the river Arigna, about one mile from Lough Allen, were the only works hitherto erected in Ireland to smelt iron with coal, and have therefore attracted much attention. The works as first constructed were divided into two distinct parts, the upper and lower works. The iron was smelted and all the castings were made in the upper

works, and the lower were confined to rendering cast-iron malleable, forming it into bars, &c.

The upper works, in the beginning of the century, when reported upon by Mr. John Grieve, "consisted of a blast furnace 44 feet high and 12 feet wide in the boshes; the furnace bank descending to the bridge-house and tunnel head; so that the materials were thrown into the furnace out of wheelbarrows. An overshot wheel of 27 feet diameter furnished the necessary blast for this furnace, and also worked a very good boring mill. There was also a foundry with a cupola furnace."

The lower works, according to the same report, "originally consisted of a forge with a refining hearth, worked by an overshot water-wheel 16 feet in diameter, with 3 cranks on its axis, working 3 cylinder bellows, each 30 inches in diameter, a mumbling hammer, about 3 tons weight, worked by an overshot water-wheel 13 feet in diameter, and 4 feet 8 inches broad, with air furnaces, &c. &c., for puddling. A slitting mill with two overshot water-wheels of 20 feet in diameter and 4½ broad. The rollers and cutters were each 13 inches in diameter. About the time the late Sir Richard Griffith wrote (1818), these lower works were in such a ruinous state, that nothing but the stones, and some iron materials which remain, can ever be converted to any use." *

At the period referred to, the estimated cost of making a ton of pig iron, calculated from the cost of the different materials delivered at the works, is given as follows:—

	£	s.	d.
Five tons of raw coal at 4*s.* per ton	1	0	0
Four tons of ironstone at 5*s.* per ton	1	0	0
One ton of limestone	0	2	0
Expense of cokeing, roasting the ore, labour, &c.	0	10	0
Contingencies at 20 per cent.	0	10	5
Total cost of a ton of pig iron	3	2	5

In the year 1804, Mr. Thomas Guest, of the Dowlais Ironworks in Glamorganshire, reported upon the condition of the Arigna Ironworks, and estimated the cost of production as follows. He considered that the coal of the Aughabehy and Rover collieries could be delivered at 6*s.* 4*d.* per ton, and that

* "Geological and Mining Survey," Connaught Coal-field, 1818, pp. 63, 65.

the ironstone, the greater part of which must be raised on the eastern side of Lough Allen, would ultimately cost 6*s*. per ton, and the limestone 4*s*.; therefore :—

	£	*s*.	*d*.
Five tons raw coal, at 6*s*. 4*d*.	1	11	8
Four tons ironstone, at 6*s*.	1	4	0
One ton limestone, 4*s*.	0	4	0
Labour, 10*s*.	0	10	0
Rent, wear and tear, and other incidental expenses	1	5	4
Total, per ton	4	15	0

At a more recent date, in 1827, when Mr. Twigg reported to the directors of the Arigna Company, the result of his investigations led to an estimate being made of the cost of manufacture of iron, which was as follows :—*

	£	*s*.	*d*.
Five and a half tons of raw coal, at 7*s*. 10*d*.	2	3	1
Three tons four cwts. of ironstone, at 4*s*. 10*d*.	0	15	5
One ton of limestone, at 3*s*.	0	3	0
Workmen's wages, &c.	0	13	3
Cost of engine, slack, agency, &c.	0	11	0
Total	4	5	9
If limestone be supplied by railway deduct 1*s*. 11*d*. per ton	0	1	11
Final cost of a ton of No. 1 Pig	4	3	10

Sir R. Kane remarks generally upon the above estimate that it is too high, and adduces very good reasons, inasmuch as the best coal of the district, the Aughabehy, was then selling at 6*s*. 4*d*. per ton, and the coal of the Rover colliery at 4*s*. 9*d*. per ton. In the same way the ironstone is undervalued in its contents of metallic iron, 30 per cent. being taken; whereas the average contained is fully 40 per cent., which, at 4*s*. 10*d*., would cost but 12*s*. 1*d*., but two tons and a half being required. One point is quite clear that all the necessary materials for the manufacture of pig iron are found in the Arigna district in abundance.

About the year 1856, towards its close, the works at Arigna appear to have been re-opened, and the manufacture of pig iron again carried on; in the year 1857 it is recorded that 1,000 tons of pig iron were produced by the single blast furnace then in operation. Soon afterwards the works appear to have been closed, and subsequently abandoned.

* "Industrial Resources of Ireland," 2nd edition, 1845, p. 147.

CHAPTER XXIII.

FOREIGN IRON ORES IMPORTED.

General Description of these Ores—Their mode of occurrence—Analyses of Ores—Quantities imported from Spain, Portugal, France, Algeria, Italy, Greece, Norway, Sweden, Russia, and Turkey in Asia—Bauxite and Analyses.

Spain, especially rich in her deposits of ironstone, furnishes large supplies to Great Britain; indeed, the deposits may be said to be almost inexhaustible. In the early part of the past decade the unsettled condition of affairs in that kingdom greatly retarded the development of this important industry. In recent years, however, a more prosperous condition appears; thus in 1860 the total imports of iron ore into the ports of the United Kingdom did not exceed 20,542 tons, while in the year 1870, when the industry was assuming importance, the quantities received in this country had increased to 179,083 tons, showing an increase four-fold in a period of six years; yet ten years later the imports amounted to 2,278,962 tons.

The more important deposits of iron ore are found in the carboniferous limestone, the most extensive at Bilbao, near the port of the same name, where at the Somorrostro mines upwards of 1,000 tons are daily raised. The other important deposits yielding valuable ores, are situated near Carthagena, Catalonia, Granada, and Santander.

In referring generally to these valuable ores of iron, it will be interesting to give a brief account of the more important deposits, now so extensively worked at Somorrostro.*

"The Somorrostro ironstone district, which is situated north-west of Bilbao, is the principal seat of the industry. The centre of the district is about 7½ miles from Bilbao, and about the same distance from the shipping place on the River Nervion, between Bilbao and the sea. The known deposits of iron ore

* Abstract of a paper by E. Bourson, "On the Somorrostro Mines."

occur here and there over a large area, some deposits being found quite near to Bilbao, and others 19 miles north-west of it. The principal mass is about 2¼ miles in length by 1¼ mile in width; its thickness has not yet been proved, but the workings have been carried down to the depth of 246 feet in some places, and 105 feet in others. The ore is chiefly brown hematite, interspersed with blocks of unaltered spathic ore. It contains in the undried state from 50 to 64 per cent. of metallic iron, about 1 per cent. of manganese, but only a fractional percentage of sulphur and phosphorus." In all the localities wrought, the ore crops out to the surface, and it is consequently obtained from open workings, blasting being generally employed.

The conveyance of the ore from the mines to the railways is either in carts drawn by oxen or by wire tramways, and afterwards by rail to the shipping places. Two systems of conveyance by wire-rope are used—Hodgson's and Bleichert's. The arrangement by Bleichert has more recently been introduced; the main ropes in it are fixed, serving as rails for the trams, or tubs suspended from them to run on. The trams are drawn by a lighter running rope. The first cost is greater with Bleichert's than with Hodgson's system, but the working cost is less, and it is capable of carrying twice the quantity per day. The cost of transport by Bleichert's wire-rope line, is about 2·66*d.* per ton per mile. There are five lines of railway or wire-rope lines connecting the mines with the shipping places. The waggons are filled by hand, and are so arranged as to tip at the end or bottom.

The shipping stages are constructed of timber, the waggons being run out on them singly, then tipped into the vessels through inclined spouts, in one case by a vertical spout, over which the bottom tipping-waggons discharge. The average cost of the ore per ton on board is nearly as follows:—Quarrying, 1·04*s.* per ton; conveyance to railway by wire-rope line, ·37*s.* per ton; filling into railway waggons, carriage by rail, and transhipping, 1·65*s.* per ton; duty, ·10*s.* per ton; total, 3·16*s.*, or 3*s.* 2*d.* per ton. The quantity of ore shipped at the harbour of Bilbao in the year 1877 was 964,533 tons, increased in the year 1878 to 1,224,730 tons, of which England received 856,038 tons, and Scotland 47,445 tons.

Analyses of the Iron Ores of Spain.—At the mines of San Prudencia, in the neighbourhood of Bilbao, the ore obtained in a

nodular state from the deposit of drift is known by the name of "Small," while the ore obtained from the deposits in the carboniferous limestone is designated "Rock Ore;" of these varieties and of the rich hematites worked at the Campanil and Ollargan mines, ores in good demand and commanding a good price, the annexed analyses give the respective constituents :—

Constituents.	SAN PRUDENCIA.		CAMPANIL.	OLLARGAN.
	Small.	Rock.	Rock.	Rock.
Peroxide of iron . .	71·93	79·59	80·06	70·10
Protoxide of iron . .	...	...	5·42	...
Silica	9·77	5·34	2·00	13·66
Manganese . . .	1·95	2·02	2·10	3·65
Alumina . . .	4·23	1·97	0·40	6·33
Lime.	0·08	trace	...	0·22
Magnesia . . .	trace	trace	...	0·23
Carbonic acid . . .	...	...	3·21	...
Water and loss . .	11·39	10·81	6·71	5·71
Total . . .	99·35	99·73	99·90	99·90
Metallic iron . . .	50·35	55·70	60·25	54·00

Other analyses of Bilbao ores from three different localities show the following results; the analyses were made by the late Mr. William Baker, of Sheffield, one of the earliest Associates of the Royal School of Mines :—

BILBAO ORES.

Constituents.	No. 1.	No. 2.	No. 3.
Silica	5·55	1·70	7·65
Peroxide of iron	78·80	79·20	76·00
Alumina	3·50	6·80	5·80
Protoxide of manganese . .	0·651	2·88	0·83
Sulphuric acid	0·068	0·62	0·34
Lime and magnesia . . .	trace	trace	trace
Phosphoric acid	none	none	none
Water combined	11·653	9·672	10·128
Total	100·222	100·872	100·748
Loss in drying	0·66	1·80	1·60
Metallic iron	55·16	55·44	54·20

The ores of Spain are extensively employed in the furnaces of Durham, Cleveland, Lancashire, and Cumberland, also in Shef-

field, South Wales, and Scotland. The Deseada ore, raised by the Santander Mining Company, yielding 58·66 per cent. of metallic iron, employed in some of the Cumberland furnaces, gives the following results on analysis :—

RESULTS TABULATED.

Sesquioxide of iron	83·79	Brought forward	88·73
Alumina	0·45	Sulphuric acid	0·31
Protoxide of manganese	0·18	Sulphur	0·06
Lime	1·35	Phosphoric acid	0·09
Magnesia	0·16	Carbonic acid	0·60
Silica	2·80	Water, hygroscopic	1·19
Titanic acid	trace	,, combined	8·71
Carried forward	88·73	Total	99·69

The ores raised by the same company at their Onton mines has been examined by Dr. Noad, F.R.S. The five samples examined give the following results :—

RESULTS TABULATED.

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Water	13·60	10·80	12·80	11·80	11·00
Peroxide of iron	71·43	79·50	78·70	73·60	78·20
Silica	14·60	9·80	8·40	14·20	10·50
Total.	99·63	100·10	99·90	99·60	99·70
Metallic iron	51·00	55·65	55·00	51·06	55·00

An average of the above giving 53·54 per cent. of metallic iron.

Imports of Iron Ore from Spain.—In the following table is given the quantities and values of these ores imported into Great Britain since the year 1864 :—

Years.	Quantities.	Value.	Years.	Quantities.	Value.
	Tons.	£		Tons.	£
1859	25,701	19,273	1870	179,083	146,747
1860	20,542	13,865	1871	302,382	264,255
1861	22,208	17,423	1872	631,134	705,441
1862	33,517	24,797	1873	790,891	1,000,720
1863	38,388	26,097	1874	541,963	665,614
1864	43,927	32,887	1875	250,641	273,757
1865	37,121	29,476	1876	522,383	556,756
1866	27,619	22,160	1877	990,039	983,566
1867	67,356	54,298	1878	1,088,862	1,021,455
1868	88,770	74,635	1879	1,007,617	981,276
1869	99,816	78,134	1880	2,278,962	2,270,462

From the foregoing it appears, that in the year 1864, these ores had a value at the port of importation of nearly 15*s.* per ton, increased in the year 1873 to nearly 25*s.* per ton, since which year a gradual falling off in value appears; the returns for the year 1880 giving 20*s.* per ton.

Regarding the development of the hematite deposits of Spain, the Consular Reports, published at the beginning of 1880, are of great interest at the present time. The English consul at Bilbao reported on the iron ore trade of that district in the following terms: * —"Considering the depressed state of the iron market during nearly the whole of last year, it is satisfactory to observe that the decrease in this export was only trifling; and it may be mentioned that the export during the current year will largely exceed the most sanguine expectations entertained of the development of this trade, contracts having been made for the delivery of upwards of 2,500,000 tons of ore before the 31st of December next. The average price of the ore up to October last ruled from 6*s.* to 7*s.* per ton free on board, and at the date of this report it is 15*s.* per ton delivered at the loading wharves. Freights to England were from 7*s.* to 7*s.* 6*d.*, and iron ore from 10*s.* to 10*s.* 6*d.* (March, 1880), significant facts reflecting on the improvement in the iron trade throughout the world. About three-fourths of the ore continues as hitherto to be shipped to the United Kingdom." The total exports of iron ore from the port of Bilbao in the four years ending 1880, were as follows, the average price of the ore in June, 1881, being about 7*s.* per ton F.O.B. at port of shipment:—

Year.	Quantities.	Value.
	Tons.	£
1877	964,000	771,200
1878	1,224,000	979,700
1879	1,160,248	870,000
1880	2,345,598	...

In the following statement, from "The Revista Minera," a Spanish official return, appears the quantities of iron ore received at the several ports in England and Scotland in the years 1878 and 1879:—

* "H. M. Consular Reports" for the year 1879, p. 922.

Ports.	1878.	1879.
England—	Tons.	Tons.
Cardiff	295,300	299,085
Newport	221,041	219,783
Middlesborough . . .	133,461	36,783
Newcastle	113,479	51,771
Sunderland	48,804	30,658
Port Talbot	16,094	30,543
Swansea	11,502	11,528
Stockton	...	2,574
Maryport	6,895	...
Liverpool.	5,030	6,413
Porthcawl	...	1,307
Briton Ferry	1,311	...
Llanelly	1,271	...
Workington	...	536
West Hartlepool . . .	650	1,033
Saltney	639	244
Barrow and Chester . .	...	714
London	302	...
Grimsby	259	...
Scotland—		
Glasgow	40,734	41,496
Ardrossan	4,876	351
Troon	1,061	...
Granton	...	480
Ayr	636	...
Borrowstonness	138	...
Grangemouth	...	144
Total	903,483	735,443

The quantities received in England in 1878 amounting to 856,038 tons, and, in Scotland to 47,445 tons, compared with 692,972 tons and 42,471 tons in 1879.

The bar at the mouth of the River Nervion is a great obstruction to navigation; practically it stops the entrance during the half of each month. Vessels of large draught can cross it at spring tides only. Steamers drawing 13½ to 14 feet of water, capable of carrying a cargo of 1,000 tons, with engines of 120 horse-power, are the best adapted for the trade of this port. The freight of such vessels going back in ballast from Bilbao to Calais or Rotterdam is about 7*s*. 8*d*. per ton.

Portugal.—In this kingdom iron ore exists in abundance in nearly all the provinces; some of these ores are known to be rich in manganese, and are likely by-and-by to attract attention. The granitic rocks and metamorphic schists contain lodes of magnetite or magnetic oxide of iron; one of the most important of these is

that in the Serra dos Monges, in the province of Alentejo, which, on account of its proximity to the railway from Evora to Lisbon, is well situated for exploration on a large scale; other remarkable lodes of this ore occur at Villa Boim, near Elvas, in the same province, and at Campo Major, near the Spanish frontier. The specular oxide of iron, hematite, and spathic carbonates of iron, are also found in Portugal. At Moncorvo there are some remarkable lodes of oligist iron ore, and at Quadramil, in the province of Traz-os-Montes, a very rich lode, containing brown hematites and hydrated oxides of iron, is seen to have an extension of some 4 or 5 miles, with a breadth at places of 60 feet.

Powerful lodes of carbonate of iron are known to exist in various districts; one especially may be mentioned recently discovered rich in manganese in the province of Alentejo, the proportion of the manganese to the iron being as three to five, the percentage of phosphorus under a thousandth per cent.; the earthy matter in this ore is not more than 10 per cent., and is composed of clay, with a little carbonate of lime, so that it is expected that this ore will prove an admirable material for the production of spiegeleisen or ferro-manganese.*

The annexed analyses of the iron ores raised at Monges, in Portugal, employed in the blast furnaces of Scotland, will show their composition :—†

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.
Peroxide of iron	70·44	67·52	62·86	59·71
Protoxide of iron	18·00	7·09	7·20	8·81
Oxide of manganese	0·04	trace	trace	1·48
Lime	...	0·66	...	trace
Magnesia	...	trace	0·67	trace
Carbonic acid	...	0·46	0·63	...
Phosphoric acid	trace	0·08	0·14	0·06
Sulphur	2·38	...	...	0·17
Iron combined with sulphur	2·08	...	...	0·15
Alumina	1·22	4·70	5·49	7·17
Silica	2·76	10·83	11·72	16·20
Water combined	3·08	8·66	11·29	6·25
Total	100·00	100·00	100·00	100·00
Metallic iron	65·48	52·78	49·60	48·80

* "Journal of the Iron and Steel Institute," 1875, p. 302.

† "Iron," 7th October, 1876, p. 459. Paper by Mr. J. St. Day, C.E.

The importation of iron ore from Portugal commenced in the year 1873, when 24,812 tons, valued at £32,063 were received in Great Britain. In subsequent years the returns are as follows:—

Year.	Quantities.	Value.
	Tons.	£
1873	24,812	32,063
1874	29,398	37,969
1875	48,277	55,891
1876	12,894	13,234
1877	13,998	13,168
1878	3,154	2,946
1879	nil	nil
1880	39,775	44,433

France, though rich in her deposits of iron ore, does not export largely, but on the contrary, to meet the demands of her metallurgical works, imports iron ore from her Algerian colonies, Belgium, and other countries. Magnetic ores do not abound in France; hematitic ores are wrought in considerable quantity in the department of the Ardèche, near the towns of Privas and La Voulte, and furnishes to some extent the furnaces of the Terrenoire, La Voulte, and Bessèges companies. The ore occurs in strata between the Lower Oolite and Liassic Marl, and, as described by Professor S. Jordan, "varies in character from the red hematite, with a conchoidal fracture and agate-like texture (containing 56 per cent. of iron), to the schistous and even oolitic hematite (with only 30 per cent. of iron)." The production of these deposits does not exceed 260,000 tons per annum. Analyses of the ores show the annexed results:—

RESULTS TABULATED.

Constituents.	Privas.	La Voulte.
Peroxide of iron	58·16	79·21
Oxide of manganese . . .	trace	trace
Silica	10·90	10·50
Alumina	7·10	2·26
Lime	10·35	1·22
Phosphorus	0·325	0·49

The other constituents, namely, iron in form of protoxide, magnesia, sulphur, and loss by calcination, are not determined,

and it is remarked that these red hematites of the Ardèche have a geological situation very different from those of the north-west of England, where they are found in older rocks.

The principal repositories of iron ore in France are found in the Liassic and Oolitic rocks, the conditions of occurrence being somewhat similar to ores of the same geological age in this country, though it has been remarked that in their general character they are more argillaceous than the English ores of the same age. Brown iron ore of a sandy character, occurring in superficial deposits in the Wealden rocks, between Boulogne and Calais, where it is extensively worked at a small cost, is smelted in admixture with ore from Africa, and hematite from Spain and Cumberland, at the blast furnaces of Marquise and Outreau, the last-named furnaces being situated on the River Lianne, a short distance from Boulogne. The ores raised in this area yield from 32 to 35 per cent. of metallic iron. The most important deposit in France is the great ironstone field extending from Luxemburg through Lorraine up to and beyond Nancy, in the valley of the Upper Moselle. It occupies the upper part of the Lias formation, or, according to some geologists, it belongs to the Lower Oolites. The ore obtained in this iron field is very variable, ranging from 20 to 35 per cent. of metallic iron.

Spathose ore is obtained in a few localities in France, the principal deposit being in the Department of the Isère, where it is worked at Allevard. The constituents of three varieties of these spathose ores are given as follows by Professor S. Jordan, of Paris :—

RESULTS TABULATED.

Constituents.	Isère.	Savoy.	Pyrénées Orientales.
Protoxide of iron	48·15	50·50	61·70
Oxide of manganese . . .	3·02	8·00	4·06
Silica	4·85	...	...
Quartz and clay	...	1·00	1·34
Lime	2·50	1·70	0·21
Magnesia	0.57	0·70	...
Sulphur	0·16	...	...
Loss by calcination . . .	40·49	38·10	31·95
Total	99·74	100·00	99·26

Referring to the Boulonnais Ironworks in the Pas de Calais,

it is a curious coincidence, and worthy of note, that they should have commenced operations about the time that the Wealden Ironworks ceased; these latter were situated at Ashburnham, in Sussex, and were finally extinguished in the year 1828, the iron-works of the Boulonnais commencing operations between the years 1829 and 1834.

In the following table appear the quantities and value of all kinds of ore imported into this country from France, between the years 1864 and 1877, since which there has been no imports:—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1864	19,454	12,216	1870	10,300	6,471
1865	19,477	12,765	1873	16,761	16,522
1866	16,064	9,718	1874	20,077	19,463
1867	12,540	7,675	1875	...	...
1868	10,766	6,074	1876	...	...
1869	9,424	5,753	1877	2,110	9,910

Algeria.—This important colonial possession of France contains extremely rich deposits of iron ore; at Djebel, near Arousse, and Sfer, in the province of Oran, specular iron ore is extensively wrought, while at Mokta-el-Hadid, in the province of Constantine, magnetic iron ore is worked. The annexed analysis shows the constituents of the ore raised in the province of Oran and used in the blast furnaces of Great Britain:—

RESULTS TABULATED.

Peroxide of iron	71·00
Lime	11·09
Magnesia	1·73
Carbonic acid	10·61
Alumina	0·74
Silica	1·36
Combined water	1·87
Water at 212° Fahr.	1·60
Total	100·00
Metallic iron	49·70

Algeria, with her extensive iron ore deposits, possesses but one metallurgical establishment of any importance engaged in the manufacture of pig iron. These ironworks are situated at Atelik,

near Bona, in the province of Constantine, where pig-iron is made from the spathose ores of the district; native coal, previously coked, being employed in their reduction.

The quantities and value of the iron ores imported from Algeria appear as under in each year since 1863 :—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1863	268	201	1872	53,162	66,741
1864	1,090	788	1873	69,856	96,964
1865	3,225	2,801	1874	62,233	79,863
1866	509	492	1875	55,620	61,808
1867	nil	nil	1876	42,112	47,355
1868	326	293	1877	22,151	24,194
1869	285	319	1878	13,124	14,783
1870	2,116	1,559	1879	18,911	18,317
1871	1,640	1,803	1880	82,248	86,884

In the year 1872 the average price of these ores exceeded 25*s*. per ton, increased to 28*s*. per ton in 1873, falling in 1874 to 26*s*. per ton, since which date prices have declined, till in 1879 they realized 20*s*., increasing in 1880 to upwards of 21*s*. per ton.

Italy.—Iron ore exists abundantly in the states of the Italian kingdom.* "The chief iron ores of Lombardy are those known as spathic or carbonate of iron, and brown hematites; these are found in beds enclosed by metamorphic gneiss in the neighbourhood of the lakes of Como and Iseo, and in the Val Sassina, also in the Bergamask Mountains, where they compose layers or seams, sometimes two and even three fathoms thick in triassic red sandstone or green slate. The brown hematite contains much manganese, and is therefore particularly suitable for the production of manganiferous spiegeleisen or a white radiated pig iron." In the island of Elba, on the eastern side, at Rio Albano, Rio Marina, Terranera, and Capo Calamita, specular iron ore, red hematite, and magnetic ores, are still wrought as they were centuries ago. The mines at Elba furnished the Etruscans with iron ore, from which they made iron long before the foundation of ancient Rome; and the mines are now far from being exhausted. The oldest mines in Elba are those of Rio Marina, but the operations in recent years are confined to picking the rich ores from

* "Reports of the Vienna Exhibition, 1873," vol. iii. p. 423.

the heaps left by the old miners; these heaps in some places attaining a height of 500 feet. The production of iron ore in Elba exceeds 200,000 tons per annum, the greater part of which is exported to Corsica, France, England, and Germany, about 40,000 tons being smelted in Tuscany, at Follonica, Cecina, Valpiana, and other places.

The deposits of Rio Marina are specular iron ore, and red hematite resting upon talcose schist, and covered by crystalline limestone, having an area of about 30 acres, the depth of the deposit being considerable. At Rio Albano and Terranera the lodes of specular iron ore break through the talcose schist, and cover it with beds of the same material from 30 to 100 feet thick; and at Capo Calamita there is a lode of magnetic iron ore which, rising from the level of the sea, intersects a thick crystalline limestone, sending frequently branches into the latter, and surmounting it by a large bell-shaped mass which attains a thickness of 150 feet, composed chiefly of specular iron ore, red hematite, actinolite, and green garnet. The iron ores above referred to yield respectively of metallic iron 66·27 per cent., 65·35 per cent., and 61·81 per cent. The following analyses show the composition of these ores; those of Calamita and Terranera are by Professor Sestini; that of Rio Albano was made in the laboratory of the Phœnix Ironworks in Germany:—

RESULTS TABULATED.

Constituents.	Calamita.	Terranera.	Rio Albano.
Sesquioxide of iron	94·67	93·36	87·84
Oxide of manganese	0·33	trace.	0·07
Alumina	...	0·58	3·47
Lime	...	0·16	0·22
Magnesia	...	0·17	0·34
Silica	3·28	...	5·97
Copper	0·04	...	...
Sulphur	0·03	0·11	0·17
Phosphorus	trace.	...	0·01
Insoluble rock	...	3·64	...
Water and loss	1·65	1·98	1·91
Total	100·00	100·00	100·00
Metallic iron	66·27	65·35	61·81

Imports of Iron Ore from Italy.—These are considerable,

although great fluctuations appear in recent years; since 1864 the quantities imported into this country, with the value in each of the same years, are given as follows in the "Trade and Navigation Returns:"—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1864	6,224	6,221	1873	31,729	46,545
1865	4,289	4,271	1874	33,394	46,938
1866	1,292	1,292	1875	40,109	46,859
1867	*	...	1876	60,620	63,302
1868	*	...	1877	86,301	86,836
1870	119	445	1878	48,771	46,104
1871	3,320	3,167	1879	43,763	49,713
1872	47,755	61,091	1880	176,750	182,556

The average price of these ores previous to 1872 was about 20*s.* per ton; in 1872 they rose to 25*s.* 6*d.* per ton, and in 1874 to 28*s.* per ton, since which prices have receded, not exceeding 22*s.* 6*d.* per ton in the year 1879, and 20*s.* 8*d.* in 1880.

Greece.—The iron ores obtained from the Grecian Archipelago are found in the Island of Seriphos. The deposits consist both of magnetic iron ore and of brown hematite, similar to the Bilbao ore, but in some of the mines strongly manganiferous. The magnetic ores have not hitherto been worked, as they are not so favourably situated for transport as the brown hematites. These occur as beds interstratified with calcareous shales and marbles, and often forming the surface stratum, so that they can be worked simply by open quarrying; and, as they are situated close to the coast, ships can lie within a few hundred feet from the mines themselves, by which the expense of extraction is reduced to a minimum. As to quantity, although the works are of small extent and principally open quarries, enough has been opened out to prove more than a million tons of ore, and there is no reason to doubt the continuance of these iron ore beds in depth. The ore raised and imported into this country from the mines in the Island of Seriphos was smelted some years ago with very satisfactory results, at the Royal Greek Ironworks, situated at Wallsend, near Newcastle-upon-Tyne. The quality of the ore was excellent, as may be seen by the following analyses, made by Mr. John Pattinson, of Newcastle, from the different mines:—†

* Not separately distinguished.

† "Journal of the Iron and Steel Institute," 1875, p. 293.

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.
Peroxide of iron	80·64	81·64	66·07	67·55
Sesquioxide of iron	0·96	1·41	...	...
Peroxide of manganese	0·98	1·75	6·91	8·73
Alumina	1·20	0·40	0·40	0·20
Lime	1·90	2·55	9·83	8·65
Magnesia	0·63	0·51	0·39	0·48
Carbonic acid	...	0·76	6·90	6·80
Silica	7·23	5·43	3·67	3·47
Sulphur	trace.	trace.	0·06	0·02
Phosphoric acid	0·07	0·05	0·06	0·07
Combined water	5·68	5·08	4·61	4·43
Moisture	0·81	0·76	1·37	1·57
Total	100·10	100·34	100·27	101·97
Metallic iron per cent.	57·20	58·25	46·25	45·90
Manganese per cent.	0·61	0·89	5·62	7·33

The reduction of these ores commenced in the works above-named about the year 1873, north country coke being alone employed, the pig iron produced by its superior quality proving the high character of the ores, which, being in part calcareous, are mixed with one another when charged into the blast furnace, so as to require no limestone or other flux to assist in their reduction. The pig iron produced has proved of admirable quality, and well adapted for conversion into steel by the Bessemer process, while puddled steel has also been made from it. Owing to the quantity of manganese contained in the pig iron, it is considered to be particularly well suited for the manufacture of steel.

The quantities imported do not appear regularly in the official returns, being included with ores received from other countries; in 1875, however, the quantities imported amounted to 10,249 tons, valued at £14,736, giving an average of 26*s*. per ton.

Norway.—The ores of Norway are chiefly magnetic, and have been wrought from a remote period. The principal deposits are found in the neighbourhood of Kragero and Arendal, and have a range of many miles in a direction parallel to the coast, occurring in hornblendic and micaceous schists. The mines near Arendal are situated at Langsev and Solberg. At Langsev and at the Barbo, an adjoining mine, a large rock of garnet is intimately mixed with augite, calcspar, and magnetic iron ore; where the latter forms concentrations, which are sometimes 3 to 4 fathoms thick, and contain from 30 to 40 per cent. of iron, the

ore is obtained in open quarry workings. The Solberg Mine produces a similar ore, being a mixture of magnetic iron ore, garnet, augite, and calcspar, and both ores are smelted without a flux, yielding a pure and exceptionally strong iron. The deposits are not extensively worked, as the yield of metallic iron does not exceed 40 per cent., and consequently the ores are not exported to any great extent.

Since the year 1865 the quantities of iron ore imported into Great Britain from the mines of Norway appear in the annexed table, with the respective values:—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1865	5,850	8,372	1872	21,014	25,098
1866	4,857	5,441	1873	16,651	17,985
1867	5,560	5,367	1874	28,680	32,786
1868	12,073	10,503	1875	24,192	26,813
1869	16,556	12,822	1876	8,749	8,927
1870	15,928	12,532	1877	5,865	6,421
1871	2,264	1,975	1878	1,023	978

The imported quantities from Norway show a great falling off since 1875 from 24,192 tons to 1,023 tons in 1878, and in the year 1879 the name has disappeared from the customs returns. In 1874, the year of greatest importation, the average price of these ores was 22*s.* per ton.

Sweden.—Ores of iron exist in abundance in this kingdom, although mineral fuel is almost entirely deficient, and the little it possesses has not yet been utilised in its iron industries. The iron ores of Sweden are either magnetic iron ore or specular iron ore and hematite, principally found in metamorphic gneiss; also bog iron ores. The most celebrated mines are those worked at Taberg, in Jonkoping, where a greenstone, containing over 30 per cent. of iron and 6·2 per cent. of titanium and vanadium, constitutes a whole mountain. Another important district, Upsala county, may be mentioned, where are situated the celebrated mines of Dannemora. Bog iron is extensively raised in the counties of Jonkoping, Kronoberg, Kalmar, and Skaraborg; this ore is chiefly reduced in the blast furnaces of the localities named, where foundry pig iron is made, the iron thus made containing so much phosphorus as to unfit it for conversion into malleable iron, it is therefore exclusively employed for the production of light castings, such as stoves, kitchen ranges, and hollow ware.

The iron ores of Sweden imported into Great Britain are inconsiderable, not exceeding 5,850 tons in any one year since 1865. It will, however, be interesting to note the imports and values in each year since 1861, which are as follows; importation ceasing in 1877:—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1861	376	313	1870	15	37
1862	554	533	1871	397	397
1863	270	358	1872	625	1,884
1864	1,984	1,804	1873	436	1,847
1865	5,850	8,372	1874	41	322
1866	4,685	6,746	1875	143	740
1867	305	475	1876	23	147
1868	1,506	2,258	1877	91	431
1869	835	1,251			

Analyses of Swedish Ores.—The following five important varieties illustrate the ores of Sweden, the Dannemora ore No. 1 being especially employed for producing the highest class of steel iron, is referred to as a fine-grained magnetite. In the first analysis, by Ward, the ore is described as a compact black mineral, containing a very small trace of iron pyrites. The second and third, by Noad, are of magnetic ores from Roslagen, on the east coast of Sweden, north of Stockholm; the fourth is of a lake ore from Flaten, Wermland, by Svanberg;* and the last a titanic ore.

RESULTS TABULATED.

Constituents.	No. 1.	No. 2.	No. 3.	Lake Ore.	Titanic Ore.
Peroxide of iron	58·93	62·06	56·80	67·59	54.00
Protoxide of iron	27·55	28·42	27·50	...	28·29
Protoxide of manganese	0·10	...	0·24	...	...
Oxide of manganese	...	...	...	1·45	...
Lime	0·38	trace.	1·80	0·47	...
Magnesia	0·61	1·44	0·80	0·23	...
Alumina	0·29	...	...	4·18	0·96
Silica	12·54	7·60	13·20	7·81	3·05
Titanic acid	...	...	...	...	13·50
Carbonic acid	0·12	...	...	...	...
Sulphur	0·04	0·07	...	0·18	...
Phosphoric acid	trace.	...	...	...	...
Water	0·11	...	...	17·81	0·20
Total	100·67	99·59	100·34	99·72	100·00
Metallic iron	62·60	65·60	61·16	47·32	59·80

* Bauerman, "Metallurgy of Iron," pp. 62, 79.

Russia.—Ores of iron have in recent years been imported from this distant empire in notable quantities, commanding a very high price, inducing to the belief that they contain chromate of iron.

"The chromic iron ore of the Ural mountains forms masses, nests or veins, in serpentine. The richest kind contains 60 per cent. of chromium, but it is usually less, going as low as 30 per cent., the average being from 52 to 54 per cent.; often it is so intimately mixed with magnetite, that it ceases to be a chrome ore proper. (The deposits are mostly on the eastern slope of the Ural mountains.) Since 1862 they have been in demand for export, but the cost of transport is so great that ores below 50 per cent. are practically unsaleable." *

Russia is comparatively rich in iron ores, considerable deposits of brown hematite occur in Western Russia in the district of Bieloi; where the upper bed, described as "a brown hematite," mixed with clay and sand, is found at a depth varying from one to seven feet from the surface, the overlying soil being a reddish-yellow clay. This bed of iron ore varies in thickness from 20 to 30 inches, and in many parts is succeeded by another bed of similar ore from seven to fifteen inches in thickness. The chemical analyses of the ores of the above-named district made at Moscow and St. Petersburgh show it to be an hydrated peroxide of iron, with an admixture of sand and clay containing from 29·70 to 35·00 per cent. of metallic iron. Similar ores are said to occur in more than twenty localities situated from each other about fifteen miles in the same district.

Appended are the quantities and values of the ores imported from Russia in each year since 1870, according to the "Trade and Navigation returns":—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1870	7,892	58,415	1875	3,602	28,641
1871	3,888	23,334	1876	4,866	31,076
1872	14,236	94,481	1877	6,339	45,486
1873	4,668	37,600	1878	8,051	49,328
1874	12,244	94,527	1879	4,043	22,455

The total quantity of ore imported in the year 1880 amounted to 15,723 tons, of the declared value of £98,264, giving an average value of nearly £6 5*s.* per ton.

* Aperçu des Richesses Minérales de la Russe, p. 106.

Turkey in Asia.—The ores imported from Turkey, like those from Russia, are of a valuable description, and in all probability of the same character, containing perhaps some chromate of iron. The quantities annually imported since 1866 appear in the following table, with the values :—

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1866	436	2,680	1873	1,329	10,927
1867	507	3,140	1874	835	5,630
1868	1,427	10,850	1875	6,538	46,921
1869	1,717	4,800	1876	7,778	54,577
1870	4,426	29,140	1877	12,016	70,942
1871	6,032	37,923	1878	3,215	16,456
1872	4,090	23,295	1879	4,881	34,271

The imports in the year 1880 amounted to 10,683 tons, of the value of £71,897, giving an average value of nearly £6 5*s*. per ton.

Total Imported Ores.—With the foregoing general reference to those countries furnishing supplies of iron ore to the United Kingdom, and the localities of some of the more important deposits, it only remains to give the total quantities and values in each year, which are here appended :—

Iron Ore imported into Great Britain.*

Year.	Quantities.	Value.	Year.	Quantities.	Value.
	Tons.	£		Tons.	£
1863	62,167	46,486	1872	801,503	1,014,842
1864	74,163	55,702	1873	967,536	1,278,278
1865	76,977	72,491	1874	754,141	1,021,481
1866	56,689	49,081	1875	458,693	583,571
1867	86,569	69,218	1876	672,235	795,510
1868	114,438	94,620	1877	1,142,308	1,256,069
1869	131,321	101,644	1878	1,173,860	1,161,638
1870	208,310	166,190	1879	1,083,692	1,037,719
1871	324,034	343,175	1880	2,634,401	2,792,717

The returns for 1880 show a remarkable increase over the previous year; the largest importation coming from Spain. Prices showing an upward tendency, from nearly 20*s*. per ton, in the year 1879, to 22*s*. per ton in the year 1880.

The aluminous ore known as "Bauxite," though not imported into this country, possesses much interest from the fact that it is

* Trade and Navigation Returns.

employed in some of the Continental iron works, where, in recent investigations on the dephosphorisation of iron and steel, considerable attention has been given to it and its constituents. Seven varieties, subjected to analysis by M. de Wendels, confirming others made by M. Fovey, show the following results. It being remarked that it is impossible to procure bauxite containing much less than 10 per cent. of silica :—

RESULTS TABULATED.

No.	Kind of Bauxite.	Silica.	Alumina.	Peroxide of iron.	Lime.	Value.
						Francs.
1	White	10·40	66·99	5·71	...	16
2	Rose coloured . . .	10·90	67·21	5·14	...	14
3	Red	11·80	53·46	23·99	...	10
4	Reddish brown . . .	11·90	53·51	23·99	...	8
5	Dark reddish brown of compact quality .	34·50	29·44	23·26	...	5
6	Red with pisolitic iron ore grain . . .	9·80	41·62	35·08	3·15	6
7	Gray with pisolitic iron ore grain . . .	9·70	41·54	35·46	3·10	5

The value of the bauxite delivered at Arles or Tarascon, near Marseilles, varying, according to quality, from 4*s.* to 12*s.* 6*d.* per ton.

It is explained, in reference to the above analyses, that the specimens were previously dried and calcined. The amount of water contained in the ores *in situ* varying, according to the season, from 12 to 22 per cent. The ores referred to as Nos. 4 and 6 are employed as fluxes, with Algerian ores, in the blast furnaces at Beaucaire, situated near Tarascon.

An Italian Company, some years since made many experiments to use bauxite, for the production of iron. The final result, however, was a failure with considerable loss. Bauxite was formerly used in this country and in France for the production of aluminium, as it was found that the alumina existed in a state of much purity in this ore.

The only deposit of bauxite wrought in the United Kingdom is that worked by the Irish Hill Mining Co., at their Irish Hill and Straid Mines, situated near Ballyclare, in the County Antrim, on the north-east coast of Ireland.*

* For Analyses, see page 773.

CHAPTER XXIV.

FLUXES (LIMESTONES) USED IN PIG IRON MANUFACTURE.

Fluxes (Limestones) used in the reduction of the Ores of Iron in the Blast Furnaces of Great Britain—Description and Analyses of Fluxes used in Durham and Northumberland and the North Riding of Yorkshire—Cumberland—Lancashire—North and South Staffordshire—Northamptonshire—Wiltshire—South Wales and Scotland.

Fluxes (Limestones) used in Pig Iron Manufacture.—*North of England, Durham, Northumberland, and North Riding of Yorkshire.*—The principal flux employed by the iron smelter in the above-named counties is limestone, this material exists abundantly in the districts under review. Adjoining the town of Stanhope the carboniferous or mountain limestone is extensively wrought, furnishing the chief part of the limestone used in the blast furnaces in which the Cleveland stone is smelted. At Stanhope it constitutes a rock of great thickness and is very readily excavated from a bed of from 60 to 70 feet in thickness, lying immediately under the alluvial covering. While speaking of the limestone, it may be mentioned that it is traversed in some places by metalliferous veins occasionally rich in lead, containing among other minerals carbonate and hydrated peroxide of iron.

The composition of the mountain limestone is exhibited in the following analysis:—

RESULTS TABULATED.

Insoluble in hydrochloric acid	2·00
Peroxide of iron and alumina	0·98
Magnesia	1·08
Lime	53·35
Carbonic acid	43·02
	100·43

The lime manufactured from this stone is valuable as an agri-

cultural manure, and is also employed for purifying gas, tanning, and other chemical purposes.

The limestone used at the Stockton Iron Works obtained from the Broadwood quarries described as "dark gray in colour, and crystalline;" and another variety used at the Iron Works of the Weardale Company, "slatey gray in colour and containing fossil shells," show the following constituents: both samples were dried at a temperature of 212° Fahr.:—

RESULTS TABULATED.

Constituents.	Stockton.	Weardale.
Carbonate of lime	95·92	95·55
Carbonate of magnesia . .	1·85	3·20
Carbonate of iron	0·53	trace
Carbonate of manganese . .	trace	...
Siliceous matter	1·70	0·90
Carbonaceous matter . . .	...	0·23
Organic matter	trace	...
Phosphate of lime . . .	...	0·12
Total	100·00	100·00

Another limestone (locality not stated) employed at the South Bank furnaces, Middlesborough-on-Tees, described as "dark gray crystalline limestone," gives the annexed composition in 100 parts.*

RESULTS TABULATED.

Carbonate of lime	83·65
Carbonate of magnesia	13·43
Carbonate of iron	1·71
Carbonate of manganese	trace
Phosphate of lime.	trace
Carbonaceous matter	0·39
Sand and clay	0·64
Water and loss.	0·18
Total.	100·00

The Hobberlaw limestone, in the neighbourhood of Alnwick, and the limestone obtained at North Sunderland, examined by Mr. Hugh Taylor, of Cramlington, show the following results. It is remarked of the limestones of these districts, that although they differ but little in colour from the rock in other localities,

* "Cast Iron Experiments," Return No. 497, 1858, p. 35.

yet they answer all the requirements of the iron smelter, as carbonate of lime enters so largely into their composition:—

Constituents.	Hobberlaw.	Sunderland.
Carbonate of lime	96·986	96·637
Carbonate of magnesia . .	1·006	1·938
Peroxide of iron and alumina .	·590	·526
Sand	1·209	·707
Total	99·791	99·808

The carboniferous limestone of Holy Island, distinguished by a "Top" and "Bottom Bed," exhibits some remarkable conditions, from the quantity of carbonate of magnesia contained in the top bed exceeding 35 per cent.; the respective constituents appear in the annexed analyses:—

Constituents.	Top Bed.	Bottom Bed.
Carbonate of lime	59·280	96·234
Carbonate of magnesia . .	35·121	2·076
Iron and alumina	3·746	·242
Sand	1·384	1·273
Total	99·531	99·825

The Permian limestone of Raisby Hill and the carboniferous of Harmby, largely employed by the iron smelter, also chalk, which is used in small quantities in admixture with the limestone, exhibit the following results on analyses; it may be observed that the chalk is obtained from the south of England, from whence it is brought by coasting vessels to the northern parts:—

Constituents.	Raisby.	Harmby.	Chalk.
Carbonate of lime	97·54	95·26	96·15
Carbonate of magnesia . .	0·90	2·21	1·32
Alumina and peroxide of iron .	1·35	2·98	3·20
Total	99·79	100·45	100·67

Cumberland.—The aluminous ores of the County Antrim, in the North of Ireland, are extensively used as a flux in the iron works of Cumberland, in admixture with the hematite ores.

These ores are fairly represented in the annexed analyses of two samples by Mr. C. Tookey; an analysis of bauxite, by Mr. Bell, is given side by side:—

Constituents.	Aluminous Ore.		Bauxite.
Silica	9·75	9·87	2·8
Alumina	27·95	34·57	57·4
Peroxide of iron	35·91	27·93	25·5
Protoxide of iron	6·57	5·08	...
Protoxide of manganese	0·05	traces	...
Lime	0·60	0·91	0·2
Magnesia	0·20	0·62	...
Potash	0·49	...	...
Titanic acid	...	3·51	3·1
Volatile	18·60	19·36	11·0
Total	100·12	101·85	100·0

The limestone abounding in the Whitehaven district is very generally used as it is a good material. It is described as "fine grained crystalline; light brownish-gray in colour, and containing fossil shells (terebratula);" * on analysis this limestone gives the following results:—

SAMPLE DRIED AT 212° FAHR.

Carbonate of lime	97.63
Carbonate of magnesia	1·03
Carbonate of iron	0·24
Carbonate of manganese	0·11
Sulphate of lime	0·07
Phosphate of lime	trace
Carbonaceous matter	0·06
Alumina	0·10
Silica (principally sand)	0·76
Total	100·00

The ordinary black shale of the coal measures, consisting of clay and carbonaceous matter, and not containing an appreciable amount of sulphur, has occasionally been employed as a flux.

Lancashire. *Fluxes employed.*—The shale of the coal measures sometimes used as a flux is thus composed. The sample examined by Dr. Frankland was obtained from the neighbourhood of Manchester:—

* "Cast Iron Experiments," Return No. 497, 1858, p. 19.

COAL MEASURE SHALE.

Silica	61·91
Alumina	21·73
Protoxide of iron	4·73
Lime	0·09
Magnesia	0·59
Potash	3·16
Soda	0·25
Volatile matter	7·43
Total	99·89

The carboniferous limestone of Lancashire in which the hematite occurs affords a plentiful and good supply; that used at Askam is obtained from a neighbouring quarry at Stainton, and has the following composition:—

ANALYSIS OF STAINTON LIMESTONE.

Carbonate of lime	95·00
Carbonate of magnesia	4·20
Silica	0·50
Oxide of iron and alumina	0·30
Total	100·00

The aluminous ores of the North of Ireland from the County Antrim are also to some extent employed in admixture with the ores of Furness and Whitehaven, as a means of producing a better slag and to some extent controlling the percentage of silica in the pig iron. These aluminous ores are of several varieties, containing from 20 to 27 and as much as 35 per cent. of alumina, and will be found fully described with their respective analyses in the section devoted to the iron ore deposits of Ireland.

North Staffordshire.—The limestone raised from the Froghall quarries, and used at the Goldendale Iron Works, near Stoke-upon-Trent, described as "light coloured and crystalline," gives the following constituents on analysis:—

SAMPLE DRIED AT 212° FAHR.

Carbonate of lime	97·89
Carbonate of magnesia	0·87
Carbonate of iron	0·48
Carbonate of manganese	traces
Phosphate of lime	trace
Silica (sand)	0·63
Total	99·87

South Staffordshire.—The Silurian limestone of Dudley is extensively employed in the furnaces of South Staffordshire and Worcestershire. The varieties used in the Netherton furnaces and the Park Head furnaces, derived from the Dudley quarries, are described as "light-coloured and crystalline," average samples being selected for analysis from fine and coarse grained specimens, giving the annexed results :—

Constituents.	Netherton Furnace.	Park Head Furnace.
Carbonate of lime	97·31	97·10
Carbonate of magnesia . .	1·00	0·85
Carbonate of iron . . .	0·62	0·60
Clay and sand	1·27	1·15
Organic matter and water .	0·20	...
Water and loss	...	0·30
Total	100·40	100·00

Another limestone obtained from the Springfield quarry, Dudley, used at the Old Hill furnaces, being described as "light-coloured, crystalline; with a small vein of quartz running through the sample," exhibits the annexed constituents. In each case the limestone was dried at 212° Fahr. :—

Carbonate of lime	88·85
Carbonate of magnesia	2·03
Carbonate of iron	1·21
Phosphoric acid	0·26
Siliceous matter	8·15
Total	100·50

Traces of carbonate of manganese and organic matter were also found, it being further ascertained that the siliceous matter consisted of quartz with a little clay.

Northamptonshire.—The materials principally employed are light-coloured argillaceous limestone and chalk; of the former, two varieties may be referred to, the one "pale yellow in colour, and oolitic in structure;" the other "light-coloured and composed entirely of an agglomeration of fossil shells;" while the chalk is of the ordinary description, consisting of carbonate of lime, with traces only of silica, alumina, peroxide of iron and carbonate of magnesia. The two following analyses of limestone are obtained

from samples dried at a temperature of 212° Fahr., and have the following constituents:—*

RESULTS TABULATED.

Constituents.	No. 1.	No. 2.
Carbonate of lime	89·36	96·86
Carbonate of iron	3·38	1·36
Carbonate of magnesia	0·97	0·90
Siliceous matter	...	0·88
Organic matter	trace	...
Ferruginous clay and sand	6·00	...
Water	0·43	...
Total	100·14	100·00

The first named variety was formerly employed at the East End Ironworks, near Wellingborough, of Messrs. Butlin and Co. These works have been for some years dismantled; and the second variety at the Heyford Iron Works, near Weedon, during the occupation of Messrs. Judkins and Co.

Wiltshire.—The rocks of the immediate neighbourhood yield the required materials, two varieties are at hand, and are advantageously used as reducing agents in the smelting operations of the blast furnace. The one a limestone, oolitic in character, the other a hard chalk, both rich in carbonate of lime, which will appear in the following analysis of each variety:—

Constituents.	Oolitic Limestone.	Hard Chalk.
Carbonate of lime	91·833	93·104
Magnesia	0·796	0·188
Oxide of iron	0·885	...
Oxide of manganese	0·721	...
Alumina	1·102	trace
Potash	0·584	...
Soda	0·610	...
Sulphuric acid	0·897	...
Phosphoric acid	trace	...
Silica	1·204	1·110
Chloride of sodium	...	trace
Carbonate of iron	...	2·677
Phosphate of lime	...	0·523
Sulphate of lime	...	0·132
Organic matter	...	1·865
Water and loss	1·368	0·401
Total	100·00	100·00

* "Cast Iron Experiments," Return No. 497, 1858, p. 113.

The Westbury Iron Company (Limited) in the year 1862 contributed a most interesting and instructive series of the materials employed, and the products of their furnaces, to the exhibition of London in that year, and at the close of the exhibition presented the collection to the Museum of Practical Geology, where it was in due course deposited and may be examined. The case containing the collection will be found on the principal floor, at the south east corner, amongst the specimens illustrating the manufacture of iron. It comprises samples of the Wiltshire ore from Westbury, of the brown and green varieties, of which analyses appear in a previous page, as well as the oolitic limestone and hard chalk used as fluxes; examples of the iron made from Nos. 1 to 4 are included, exhibiting the structure and character of each variety, and the cinder obtained therefrom.

Bright iron, white iron, and mottled iron, also refined metal, are illustrated in the series, together with a sample of the cinder produced by each variety. There also appears in this collection some very curious and interesting products derived from the furnaces, amongst which may be named Cyano-Nitride of titanium, and an artificial graphite known as "Kish."

South Wales.—Few of the ores of iron are found to contain earthy ingredients in proportions sufficient to form readily fusible slags alone, it therefore becomes necessary to supply the deficiency. This is done by the admixture of ores of dissimilar character; for instance, siliceous with calcareous ores or both with argillaceous ores in such quantities as shall yield slags of the desired composition, or by the addition of calcareous or aluminous minerals not containing iron. The principal flux employed by the iron smelter is limestone, usually obtained from a neighbouring quarry, the varieties selected being such as contain the greatest amount of carbonate of lime. In the case of the rich red hematite ores of the West Coast of Ulverston and Whitehaven, argillaceous fluxes are necessary in addition to limestone. Aluminous ore obtained from the County Antrim, and known as "Belfast aluminous ore," containing a large quantity of free alumina, has in recent years been extensively used.

Of the fluxes used in the South Wales furnaces, those situated in the eastern area of the coal-field in Monmouthshire employ two varieties of limestone, known as "rough" and "smooth;" these are employed at the Blaenavon Iron Works, and are thus

described in the Report of cast iron experiments made at Woolwich, as follows :—

1. "Rough limestone" has a large crystalline structure, is light brown in colour, and contains numerous fossil shells.

2. "Smooth limestone" has an oolitic structure and is usually pale in colour.

SAMPLES DRIED AT 212° FAHRENHEIT.

Constituents.	Rough.	Smooth.
Carbonate of lime	98·55	99·26
Carbonate of magnesia . .	0·54	0·63
Carbonate of iron	0·50	0·33
Phosphate of lime . . .	0·03	0·02
Silica (sand)	0·73	0·27
Total	100·35	100·51

Scotland.—Analyses of limestones employed in the iron furnaces of Scotland. The following are some of the most important, examined by Mr. St. John V. Day, C.E., of Glasgow, and published in "Iron" in 1876 :—

Constituents.	1.	2.	3.	4.	5.	6.
Lime . .	50·46	51·97	51·93	52·35	49·30	47·98
Magnesia . .	·62	·29	·60	·21	·49	1·71
Protoxide of iron . .	·48	·90	·66	·16	·51	·98
Carbonic acid .	40·57	41·61	41·72	41·44	39·57	40·02
Phosphoric acid	·05	·09	·16	·02	·02	·17
Sulphur . .	·12	...	·21	·16	·26	·32
Iron combined with sulphur	·11	...	·18	·14	·23	·28
Alumina . .	2·61	·92	1·25	1·48	2·42	2·54
Silica . . .	4·88	2·48	1·92	2·64	6·60	4·80
Organic matter	trace	1·44	1·07	1·10	·40	·84
Water . .	·10	·30	·30	·30	·20	·36
Total . .	100·00	100·00	100·00	100·00	100·00	100·00
Specific gravity	2·553	2·727	2·715	2·703	2·717	2·500

CHAPTER XXV.

COAL USED IN PIG IRON MANUFACTURE IN GREAT BRITAIN.

Coal used towards the close of the past century—Mr. W. Jessop's Inquiry—Coal Commission and Mining Record Office Inquiries—Coal used in recent years since 1871—Details of Coal used and Iron made in the years 1872 and 1880—Extent of economy in each year since 1871.

Coal used in Pig Iron Manufacture.—It appears desirable, at the conclusion of a work so full of statistical details as this volume is, that a general summary should be given, directing attention to the more important points in this large inquiry. In the year 1788 the average quantity of coal employed was 7 tons to each ton of pig iron produced in the furnaces of England and Wales. Ten years later the quantity employed did not exceed 6 tons, and between 1800 and 1802 the consumption averaged but 5 tons.

Mr. William Jessop's Return, which has been frequently referred to, gives the average consumption in the furnaces of Great Britain, in the year 1840, as not exceeding 70 cwts. of coal to each ton of pig iron made.

The Report of the Royal Coal Commission in the year 1870, shows that the quantity of coal employed was 60 cwts., compared with 70 cwts. thirty years previously. Before considering in detail the advance made in recent years towards economy in the use of fuel in pig iron manufacture, it will be a fitting place to refer to some important observations recently made by the President of the Society of Engineers, on the subject of the manufacture of iron, in which he observes:—

"Competition in this and other countries, through the opening out by new railways of fresh iron and coal measures, and in consequence of every one endeavouring to do more than his neighbour, and to reduce the cost of smelting iron to the lowest

amount, has, I fear, in many instances, not contributed to the improvement in the quality of iron. The lives of blast furnaces are of very short duration, compared with what they were in the early part of the present century. I can give two instances of the length of time furnaces lasted without being blown out, and which furnaces were at the Alfreton Iron Works, Derbyshire. One blown in during the year 1812, was in blast till 1873, whilst another blown in during 1821 was not blown out until 1866. This latter furnace was visited by the members of the British Association, during their meeting at Nottingham. After the furnace was blown out, an examination showed that there had been formed a partial lining of plumbago, which protected the fire brick lining, which I think you will admit was a very remarkable incident in blast furnace practice. I do not find charcoal had been used in smelting during the earlier period of the life of these furnaces. Coke alone was used up to the year 1829, when equal parts of coal and coke were substituted. The introduction of the hot blast was the cause of all coal being used; at that time the Furnace or Tupton coal, mixed with a lower hard coal, was the fuel used. The ironstone used was the argillaceous of the coal measures, containing from 25 to 37 per cent. of metallic iron. The iron in the raw stone exists as a carbonate, and requires calcining at a cherry red heat to convert the carbonate into a peroxide of iron for smelting. Iron made from this ore is very strong indeed. The bands of ironstone, technically called 'rakes,' are some of them found with the coal seams; the blue rake lies above the lower hard coal; the kernel rake lies above the yard coal. Nine different rakes have been worked at the Alfreton Iron Works, and it was found that the greater the variety used, the better and stronger was the iron produced. I find Durham coke the best for smelting furnaces. The demand for iron being greater, and the deposits of the oolitic formation being used, iron making took a new form. Blast furnaces were constructed to produce very large quantities of pig iron, and works were erected for the purpose of using the oolitic ores alone. In consequence of not having any of the old strong argillaceous ores mixed with them, iron sometimes gets into bad repute, and makers of strong iron are sometimes to their disadvantage classed with others who do not so mix the iron ores. I find also

that the hard coal of Derbyshire gives the iron a better quality than coke as used in the north."

"Furnaces using coal do not require to be built more than 50 feet high, but those using coke are best at 70 feet or upwards. Low furnaces are undoubtedly the best for the iron ores lying in the Midland Counties, and are about 48 feet high, 3 to 3½ inch tuyeres, pressure of blast 4 to 4½ lbs., and blast heated to about 750° Fahr. A furnace of this description makes a good tenacious iron, from a mixture of ores from Lincolnshire, Leicestershire, Northamptonshire, and the argillaceous ores of Derbyshire, and smelted with the best hard coal, clean and free from pyrites. Remelting iron in the cupola should be very carefully performed. The iron should consist of a mixture of three or four kinds of pig, and the coke should be very clean and free from sulphur; or, however good the pig iron may be, the remelting will ruin the iron, make it tender, and it will not sustain nearly the strain it should do, hence some of the best founders do not sell pig iron. The metal from the blast furnace requires testing every day, and if the remelting be carefully carried out, and the castings allowed to remain in the sand long enough to prevent them being chilled, there need then be no fear of the iron not standing the required test, which generally is as follows:—

"That a bar of 1 inch square, and 38 inches long, and weighing not more than 10 pounds, will, when supported at points 36 inches apart, and loaded in the middle, sustain a weight of not less than 7 cwt. I think it would be well for every one entering our profession to go first for a time into a foundry and see for himself the varying contraction which goes on in different kinds of iron; afterwards he should go into the pattern shop. He would afterwards remember to design his works so that the iron should contract as far as possible uniformly, and so that one part should not fracture another during cooling, which is very often the case."

Returning to the question of the economy of fuel in manufacture, the year 1873, known as the year of the coal famine, led to more precise information on the subject; in that year a Committee of the House of Commons appointed to inquire into the cause of the "Dearness and Scarcity of Coal," extended its inquiries to the quantities consumed in the manufacture of pig

iron; circulars were issued to every ironmaster in the country; these were liberally responded to, and the result of the inquiry showed that in the manufacture of 6,741,929 tons of pig iron made in the year 1872, the total quantity of coal employed amounted to 17,211,729 tons, thus distributed in Great Britain:

	Pig Iron.	Coal Used.
	Tons.	Tons.
England . .	4,594,614	11,388,342
Wales . . .	1,057,315	2,607,887
Scotland . .	1,090,000	3,215,500
Total . .	6,741,929	17,211,729

These figures giving an average of 2 tons 11 cwt. of coal to each ton of pig iron made. In some districts this average was greatly exceeded, particularly in the West Riding of Yorkshire and Shropshire, where cold blast is still employed in the furnaces, in making those brands of iron for which these districts are celebrated; the average in the first-named district in 1872 was 65 cwts. of coal, and in Shropshire [illegible] cwts. of coal to each ton of pig iron made.

The Durham, Lancashire, and Cumberland districts, in which the rich coke of the Great Northern Coal Field is extensively employed, giving an average respectively of 40 cwts., 42 cwts., and 47 cwts. to each ton of pig iron made.

Again, in Scotland where raw coal is extensively used in the smelting operations of the blast furnaces, the average in 1872 was 55 cwts. of coal to each ton of iron. Of late years, however, the more general application of gas-saving apparatus in the iron works has largely contributed to economy in the use of fuel.

Taking the years 1872 and 1873 when these special inquiries were instituted as marking a new era in the history of iron and of coal used in manufacture, the annexed statement for the last-named year will afford generally reliable information and serve for comparison in the returns of production in future years.

In this table appears the numbers of furnaces in each iron-producing district, in Great Britain, the iron made, coal used, with the average yield per furnace, and of coal used to each ton of pig iron made in the year 1873:—

Districts.	Furnaces.		Pig Iron Made.	Coal Used.	Average.	
	Built.	In Blast.			Per Furnace.	Coal Used.
	Nos.	Nos.	Tons.	Tons.	Tons.	Cwts.
England—						
Northumberland	10	4	44,807	101,347	11,202	45
Durham	54	49¾	799,573	1,848,100	16,071	40
Yorkshire, North Riding . .	78	76	1,156,431	2,643,997	15,216	46
" West Riding . .	40	30	151,511	493,976	5,050	65
Derbyshire	47	39	296,468	865,350	7,601	58
Lancashire	44	36	529,271	1,108,192	14,702	42
Cumberland	48	33½	456,877	1,079,118	13,638	47
Shropshire	29	21	135,149	407,876	6,435	60
Staffordshire, North . . .	36	29	241,166	710,856	8,316	59
" South . .	142	99	673,397	1,968,580	6,801	58
Northamptonshire . . .	16	10	58,480	169,592	5,848	58
Lincolnshire	13	9	52,076	142,236	5,786	55
Gloucestershire	10	6	44,409	134,019	3,841	60
Wiltshire	7	5 }	48,944	131,293	8,157	53
Somersetshire	1	1 }				
Total England . .	575	448¼	4,688,199	11,804,532	10,406	51
North Wales—						
Denbighshire	9	5	42,773	135,180	8,554	63
Flintshire	4	3	24,690	52,098	8,230	42
Total North Wales . .	13	8	67,463	187,278	8,433	55
South Wales—						
Anthracite furnaces . . .	13	8	32,822	81,837	4,102	50
Bituminous Coal Districts { Glamorganshire.	73	51	424,384	1,047,245	8,321	49
Bituminous Coal Districts { Monmouthshire.	62	42	360,583	867,640	8,585	48
Total South Wales .	148	101	817,789	1,996,722	8,012	50
Scotland	156	126	993,000	2,730,000	7,881	55
Total Great Britain .	892	683¼	6,566,451	16,718,532	9,512	50¾

Since the year 1872 a great advance has been made in the economical use of coal in pig iron manufacture. In that year the average consumption of coal in Great Britain did not exceed 51 cwts., the returns for 1873 as given above, being slightly less, about 50¾ cwts., showing a saving of one quarter cwt. on each ton of pig iron made. The amount appears trifling, yet when considered with reference to the total production of pig iron, it gives an aggregate of nearly 835,000 tons of coal. This economy appears prominently in the annexed table, giving the quantity of pig iron made, of coal used in its manufacture, and the average quantity of coal employed to each ton of pig iron made in each of the following years:—

Year.	Pig Iron Made.	Coal Used.	Coal Used per Ton of Iron.		
	Tons.	Tons.	Tons.	Cwts.	Qrs.
1871	6,627,179	19,881,537	3	0	0
1872	6,741,929	17,211,729	2	11	0
1873	6,566,451	16,718,562	2	10	3
1874	5,991,408	15,292,201	2	11	2
1875	6,365,462	15,645,774	2	9	0
1876	6,555,997	15,598,381	2	8	0
1877	6,608,664	15,342,445	2	6	2
1878	6,381,051	14,112,005	2	4	2
1879	5,995,337	13,117,411	2	4	0
1880	7,749,233	16,982,629	2	3	3

The average consumption of coal used in the year 1874 exhibits an increase over previous years; this can scarcely be the case, and a careful consideration of the question points to the probability that in the year named too high an average was taken in the conversion of coke into its equivalent of coal. There is, therefore, good reason to assume that the average consumption of coal in that year did not exceed 2 tons 10 cwts. to each ton of pig iron made.

From the above statement it will be seen that during the past decade a saving of upwards of 16 cwt. of fuel has been effected in the manufacture of each ton of pig iron, equivalent to 26·6 per cent. in the fuel used in 1880 compared with the year 1871.

To bring out more clearly the extent of the economy secured since the year 1871, when the average consumption was 60 cwt. of coal to each ton of pig iron produced in the blast furnace, the following table has been prepared, showing the actual quantity of coal used in each year since 1871; the quantity that would have been consumed had the average of the year 1871 been maintained; and the extent of the economy in each year since 1871, between the actual returns, and the assumed, of 3 tons of coal to each ton of pig iron.

It will be seen from the annexed table that in the ten years ending 1880, the total quantity of coal used in pig iron manufacture in Great Britain, amounted to 159,902,674 tons; had the average of 1871 been maintained 196,748,133 tons would have been the quantity consumed; the extent of economy, amounting to 36,845,459 tons, therefore represents an actual saving of coal in ten years of no less than 23·00 per cent. in this branch of our national industries.

Year.	Coal Used in Pig Iron Manufacture.	Assuming Three Tons of Coal to each Ton of Pig Iron.	Extent of Economy in each Year.
	Tons.	Tons.	Tons.
1871	19,881,537	19,881,537	...
1872	17,211,729	20,225,787	3,014,058
1873	16,718,562	19,699,353	2,980,791
1874	15,292,201	17,974,224	2,682,023
1875	15,645,774	19,096,386	3,450,612
1876	15,598,381	19,667,991	4,069,610
1877	15,342,445	19,825,992	4,483,547
1878	14,112,005	19,143,153	5,031,148
1879	13,117,411	17,986,011	4,868,600
1880	16,982,629	23,247,699	6,265,070
Total	159,902,674	196,748,133	36,845,459

Of the many improvements in late years tending to economy in the use of fuel in pig iron manufacture, the enlargement of the furnace may be referred to, its increased height and capacity securing, to the utmost limits, the pressure that the coal or coke would stand without being crushed by the superincumbent weight of materials in the furnace; and enabling a greater pressure of blast to be employed. Another improvement which has of late years exercised an important influence on our iron industries, is the raising of the blast to double the temperature that was usual when the hot blast was introduced by Neilson, and for a considerable period afterwards. This is effected by the use of a firebrick "Regenerator" (such as is known as a "Siemens Regenerator"), placed inside an air-tight wrought-iron case, such firebrick being heated by the combustion of the waste gases from the top of the furnace. The cold blast to be heated is then passed in the reverse direction through this hot brickwork, so that it is raised to a temperature of 1,500 degrees Fahrenheit, or a full red heat. These stoves are known as "Cowper's Stoves," and "Whitwell's Stoves," after the names of the inventors, and are extensively employed, not only in Great Britain, but also in Continental countries, and in the United States of America.

The saving of fuel in the use of these stoves varies in different districts; twenty per cent., however, may be generally regarded as the increased make of the furnace and the economy in each ton of iron made where these arrangements have been introduced.

With these general remarks, it only remains to refer to the

volume of Mineral Statistics of the United Kingdom for the year 1880, giving the details appearing in the annexed table, of the furnaces built and in blast, of pig iron made and coal used in each iron-making district in Great Britain; to which is added the average yield per furnace, and of coal used in manufacture :—

Districts.	Furnaces.		Pig Iron Made.	Coal Used.	Average.	
	Built.	In Blast.			Per Furnace.	Coal Used.
	Nos.	Nos.	Tons.	Tons.	Tons.	Cwts.
England—						
Northumberland	4	2	750,262	1,420,766	23,445	38
Durham	72	30				
Yorkshire, North Riding	91	80	1,666,156	3,611,543	20,825	45
„ West Riding	47	33	306,560	769,519	9,270	50
Derbyshire	54	40	366,792	954,035	9,169	52
Lancashire	49	37	750,884	1,362,154	20,291	36¼
Cumberland	51	40	790,343	1,604,097	19,758	40¼
Shropshire	24	12	88,338	249,254	7,361	56¼
Staffordshire, North	36	23½	225,023	434,171	9,575	38½
„ South	137	46	384,556	878,581	8,360	45¼
Northamptonshire	23	17	178,714	470,165	10,512	52¼
Lincolnshire	21	15	207,704	481,807	13,847	46
Gloucestershire	9	2	37,351	97,550	10,672	53
Wiltshire	4	1½				
Hampshire	1	..				
Somersetshire	1	..				
Total England	624	379	5,752,683	12,333,642	15,180	42⅞
North Wales—						
Denbighshire	8	5	57,812	139,328	8,259	48
Flintshire	2	2				
Total North Wales	10	7	57,812	139,328	8,259	48
South Wales—						
Anthracite furnaces	11	4	440,915	922,155	12,970	42
Bituminous Coal Districts. Glamorganshire	74	30				
Bituminous Coal Districts. Monmouthshire	56	35	448,823	1,045,449	12,823	46½
Total South Wales	141	69	889,738	1,967,604	25,793	44¼
Scotland	149	112½	1,049,000	2,542,055	8,134	48½
Total Great Britain	924	567½	7,749,233	16,982,629	10,113	43¾

The following section arranged by Mr. Hilary Bauerman, F.G.S., shows clearly the Distribution of British Iron Ores in the various Geological Strata :—

GEOLOGICAL DISTRIBUTION OF BRITISH IRON ORES.

Formations.	Ores.	Principal Localities.	Production in 1880.
			Tons.
MIOCENE (Igneous).	Brown Aluminous.	Basalt of Antrim, Larne, Red Bay, Glenarm, &c.	234,751
EOCENE.	Nodular Carbonate.	London Clay, Dorsetshire (not worked)	..
UPPER CRETACEOUS.	..	..	..
LOWER CRETACEOUS.	Brown, Sandy.	Lower Greensand, SEEND, Wiltshire . .	..
		" Linslade, Bucks (not now worked)	..
	Calcareous, Brown.	Neocomian Tealby, Lincolnshire .	..
WEALDEN.	Nodular Carbonate.	Weald of Kent and Sussex (not now worked)	..
UPPER OOLITE.	..	..	..
MIDDLE OOLITE.	Brown Oolitic.	Coral Rag, Westbury, Wilts . . .	67,500
LOWER OOLITE.	Brown Oolitic.	NORTHAMPTON SAND in Oxfordshire . . Northamptonshire, Lincolnshire, &c. .	1,550,013
	Brown and Magnetic.	Dogger Ironstone, ROSEDALE, Yorkshire .	6,079
UPPER LIAS.	..	..	..
MIDDLE LIAS (Marlstone).	Brown Oolitic.	Adderbury, Fawler, Steeple Ashton } Oxfordshire . .	8,360
	Argillaceous Carbonate.	CLEVELAND IRONSTONE, North Riding of Yorkshire	6,480,576
LOWER LIAS.	Brown Oolitic.	Brigg, Scunthorpe, &c., N. Lincolnshire .	1,154,584
TRIAS (New Red Sandstone).	Red and Brown.	Red Hill, &c., near Bristol (included in Somersetshire).	..
PERMIAN.	..	..	..
COAL MEASURES.	Nodular Carbonates (principally).	COAL-FIELDS OF Yorkshire	286,698
		Derbyshire . . .	150,248
		North Staffordshire . .	1,350,313
		South " . .	362,773
		Shropshire . . .	226,721
		Warwickshire . .	36,972
		North Wales . . .	41,413
		South "	278,361
		Gloucester and Somerset	875
CARBONIFEROUS LIMESTONE.	Clay Band and Black Band	COAL-FIELDS OF SCOTLAND. . . .	2,659,317
	Nodular Carbonate.	Ridsdale, Northumberland	..
	Brown.	Gloucestershire and Dean Forest . .	92,159
	Red.	FURNESS and WHITEHAVEN	2,757,944
	Spathic, and Brown.	Alston Moor and Weardale (Lead District of Northumberland and Durham). .	41,859
DEVONIAN.	Spathic, Brown-Red, and Magnetic.	Somersetshire	29,818
		Devonshire	12,653
		Cornwall	15,865
SILURIAN.	Red, Brown.	Skiddaw Slate and Granite of Ennerdale, Eskdale, &c., Cumberland . . .	..
		Wicklow	4,574
	Spathic, and Brown.	Isle of Man	9
CAMBRIAN.	Magnetic Oolitic.	Tremadoc, Cader Idris, &c., North Wales	..

APPENDICES.

No. 1.—IRON ORE AND PURPLE ORE. PRODUCTION IN THE UNITED KINGDOM.

No. 2.—PIG IRON MANUFACTURE. RETURNS OF PRODUCTION SINCE 1740, AND EXPORTS SINCE 1829.

No. 3.—MALLEABLE IRON WORKS, MILLS, AND FORGES, AND STEEL WORKS;—LIST OF WORKS, AND PRODUCTION OF BAR IRON IN 1750, AND FROM 1861 TO 1880—BESSEMER STEEL WORKS IN GREAT BRITAIN AND PRODUCTION OF BESSEMER STEEL —OPEN HEARTH STEEL WORKS IN GREAT BRITAIN, AND PRODUCTION OF OPEN HEARTH STEEL—SIEMENS' REGENERATIVE GAS FURNACES FOR MELTING STEEL IN CRUCIBLES, AND PRODUCTION OF CRUCIBLE STEEL.

No. 4.—TIN PLATE MANUFACTURE. LIST OF WORKS—PRODUCTION AND EXPORTS OF TIN PLATES.

APPENDIX—No. 1.

IRON ORES PRODUCED FROM THE MINES OF THE UNITED KINGDOM—AND PURPLE ORE OBTAINED FROM METAL EXTRACTION WORKS.

TABLE I.—Iron Ore raised from the Mines of the United Kingdom.
„ II.—Iron Ores raised in the years 1860, 1870 and 1880.
„ III.—Ironstone raised from the Coal Measures in the years 1860, 1870 and 1880.
„ IV.—Purple Ore—Analyses and Quantities obtained in each year since 1871.

TABLE I.

IRON ORE PRODUCE

Raised from the Mines of the United Kingdom in each of the following Years, distinguishing the quantities of Argillaceous Carbonates and Black Bands, obtained from the Coal Measures, from that raised from Mines and Workings not in the Coal Measures:—

Year.	Ore not in Coal Measures.	Ore from Coal Measures.	Total Ore Raised.
	Tons.	Tons.	Tons.
1855	1,894,241	7,659,500	9,553,741
1856	2,673,745	7,809,564	10,483,309
1857	3,365,115	6,208,166	9,573,281
1858	2,884,065	5,156,894	8,040,959
1859	3,105,765	4,774,551	7,880,316
1860	2,858,142	5,166,063	8,024,205
1861	2,913,478	4,302,040	7,215,518
1862	3,397,531	4,164,709	7,562,240
1863	4,501,627	4,587,333	9,088,960
1864	5,107,145	4,957,725	10,064,890
1865	5,534,438	4,375,607	9,910,045
1866	5,365,167	4,299,845	9,665,012
1867	5,616,816	4,404,242	10,021,058
1868	5,822,175	4,347,056	10,169,231
1869	6,870,199	4,638,326	11,508,525
1870	7,859,477	6,511,178	14,370,655
1871	10,124,708	6,210,180	16,334,888
1872	9,632,375	5,951,982	15,584,357
1873	10,058,004	5,519,495	15,577,499
1874	9,390,214	5,454,722	14,844,936
1875	10,592,050	5,229,010	15,821,060
1876	11,182,160	5,659,423	16,841,583
1877	10,768,075	5,924,727	16,692,802
1878	10,320,593	5,405,777	15,726,370
1879	9,248,868	5,130,849	14,379,735
1880	12,627,881	5,398,528	18,026,409

Table II.

Giving the Quantities of Iron Ore raised in the United Kingdom, from Mines not in the Coal Measures, in each of the years 1860, 1870 *and* 1880 :—

Iron Ore Produce.

Counties, etc.	Quantities. 1860. Tons.	Cwts.	Quantities. 1870. Tons.	Cwts.	Quantities. 1880. Tons.	Cwts.
Cornwall . . .	23,953	4	11,214	4	15,865	3
Devonshire . . .	3,836	0	10,193	17	12,652	15
Somersetshire . .	24,102	0	18,764	7	29,318	0
Gloucestershire . .	90,466	0	183,503	9	92,159	0
Wiltshire . . .	76,201	0	101,423	0	67,500	0
Hampshire . . .	6,119	0	...		...	
Oxfordshire . .	5,833	0	38,803	17	8,360	0
Northamptonshire . .	95,664	0	761,248	0	1,550,103	10
Lincolnshire . .	16,892	0	248,329	17	1,154,584	1
Staffordshire, North .	...		62,882	0	48,378	2
Lancashire . .	520,829	0	871,938	0	1,266,503	14
Cumberland . . .	468,782	0	1,221,303	4	1,491,440	18
Leicestershire . .	...		...		52,387	0
Yorkshire, N. Riding .	1,471,319	6	4,072,888	1	6,486,654	18
Northumberland and Durham . .	12,500	0	100,332	0	41,357	18
North Wales . .	97	0	100	0	1,603	3
South Wales and . Monmouthshire .	39,817	0	88,721	2	65,566	10
Ireland	61	0	167,832	0	238,272	4
Scotland	...		...		5,166	0
Isle of Man . . .	1,671	8	...		9	0
	2,858,142	18	7,859,476	18	12,627,881	16
*Iron Ore (Argillaceous and Black Band) obtained from Collieries .	5,166,062	14	6,511,178	0	5,398,528	0
Total iron ore raised in the United Kingdom .	8,024,205	12	14,370,654	18	18,026,409	16

* The details of production of Argillaceous Carbonates and Black Bands in each of the same years are given in the following Table III.

Table III.

Giving the quantities of Argillaceous Carbonates and Black Band Ores obtained from the Coal Measures of the Coal Fields of the United Kingdom in each of the years 1860, 1870 *and* 1880 :—

Iron Stone Produce.

Coal Fields.	Quantities. 1860.	Quantities. 1870.	Quantities. 1880.
	Tons.	Tons.	Tons.
England—			
Somersetshire . .	...	975	665
Gloucestershire . .	...	...	210
Shropshire . . .	165,500	337,627	226,721
Warwickshire . .	19,500	17,500	36,972
Derbyshire . . .	375,500	384,865	150,248
Nottinghamshire .	...	...	2,264
Staffordshire, North .	738,229	847,252	1,350,315
Staffordshire, South .	785,700	450,000	362,773
Yorkshire, W. Riding	255,700	307,717	286,698
Lancashire . . .	...	...	1,520
Durham and Northumberland . .	...	125,000	...
Wales—			
North Wales . . .	85,000	59,140	41,413
South Wales . .	590,889	471,333	278,361
Scotland—			
East Division . / West Division .	2,150,000	3,500,000	2,659,317
Ireland	45	9,768	1,051
Total . . .	5,166,063	6,511,177	5,398,528

Table IV.

Purple Ore.

In addition to the ores of iron raised from the mines of the United Kingdom, and the valuable foreign ores imported, there is another source of supply in the residue known as "Purple Ore." It is obtained from the cupriferous iron pyrites which has been treated for sulphur in the manufacture of sulphuric acid. This is roasted with an addition of salt, and then lixiviated with water in order to dissolve the chloride of copper formed. The copper is removed as a soluble chloride, and then obtained as cement copper by running the solution into vats containing scrap iron. The residue of these operations is nearly pure peroxide of iron in the form of a heavy, purplish

red powder, having the following composition, according to Mr. John A. Phillips, F.R.S., managing director of the Widnes Metal Company.

RESULTS TABULATED.*

Peroxide of iron	96·00
Lead (as sulphate)	0·75
Copper	0·20
Sulphur	0·36
Phosphorus	nil
Lime	0·40
Soda	0·10
Cobalt, arsenic and chlorine	traces
Insoluble residue	2·11
	99·92
Metallic iron	67·00

The results are computed in the dry state, but as ordinarily sold, the ore contains about 15 per cent. of water.

This oxide of iron is used in blast furnaces in form of blocks as well as in powder; viz.: at Palmer's Shipbuilding and Iron Company, Newcastle-on-Tyne; The Ditton Brook Iron Company, near Warrington; Bolckow, Vaughan and Co., Limited, Middlesborough; Messrs. Merry, and Cunninghame and Co., Glasgow; Messrs. Gjers, Mills and Co., Middlesborough, and the West Yorkshire Coal and Iron Company, Leeds. It is also used as fettling ore for puddling furnaces; being in a powder it does not require grinding as hematite does. When used in the blast furnace in those works where it is employed, it is added in the proportion of 25 per cent. to the amount of solid ore.

Mason's pyrites, as previously stated, gives on analysis 67 per cent. of metallic iron; other pyrites, the Tharsis, giving 62 per cent., and Buitron, 66 per cent. of metallic iron.

The annexed tabulated statement gives the quantities of "Purple Ore" available in each year since 1871:—

PURPLE ORE

Produced from the Metal Extraction Works in Great Britain.

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1871	200,000	1876	292,000
1872	252,239	1877	415,000
1873	275,000	1878	400,000
1874	255,000	1879	332,300
1875	280,000	1880	427,730

* Mason's Pyrites.

APPENDIX—No. 2.

PRODUCTION OF PIG IRON IN GREAT BRITAIN IN EACH IRON MAKING DISTRICT.

TABLE I.

In the following series of tables will be found the number of furnaces, with the production of pig iron, and occasionally notes of the quantities of coal used in manufacture; the earliest is for the year 1740. The flourishing and extensive works referred to by Dud Dudley no longer existed; the 300 blast furnaces mentioned by him were now reduced to 59, and their total annual produce to 17,350 tons, giving an average yield per furnace of 294 tons.

The details are as follows:—*

PIG IRON PRODUCTION IN THE YEAR 1740.

Districts.	Number of Furnaces.	Pig Iron Made.
		Tons.
Derbyshire	2	550
Gloucestershire	4	800
Hampshire	3	1,350
Kent	1	200
Nottinghamshire	1	200
Shropshire	6	2,100
Staffordshire, North	3	1,700
Staffordshire, South	2	1,000
Sussex	10	1,400
North Wales	4	400
South Wales	13	4,850
Warwickshire	2	700
Worcestershire	2	700
Yorkshire	6	1,400
Total	59	17,350

* "History of the Iron Trade." By Harry Scrivener. 1854. P. 57.

TABLE II.

For the year 1788 the following information appears, many of the charcoal furnaces having died out since 1740. In some districts the wood was exhausted; in others, the ironmaster was prohibited from using it; and in others the use of charred coal (coke), by reducing the price of pig iron, compelled the charcoal iron maker to abandon or to alter his mode of manufacture. The production of charcoal iron made was 14,500 tons, and of coke pig iron 53,800 tons, in the furnaces of Great Britain; the average make of the charcoal furnaces being 545 tons; and of the coke furnaces, 909 tons per annum. The details are as follows, and the total production 68,300 tons:—

PIG IRON PRODUCTION IN THE YEAR 1788.

Districts.	CHARCOAL PIG IRON.		COKE PIG IRON.	
	Furnaces.	Tons.	Furnaces.	Tons.
Brecknockshire	...	...	2	1,600
Caermarthenshire	1	400	...	...
Cheshire	...	...	1	600
Cumberland	1	300	1	700
Derbyshire	1	300	7	4,200
Glamorganshire	3	1,800	6	6,600
Gloucestershire	4	2,600	...	...
Lancashire	3	2,100	...	...
Merionethshire	1	400	...	...
Monmouthshire	3	2,100	...	...
Shropshire	3	1,800	21	23,100
Staffordshire, South	...	...	3	2,400
Staffordshire, North	...	...	6	4,500
Sussex	2	300	...	...
Westmoreland	1	400	...	...
Yorkshire	1	600	6	4,500
Scotland	2	1,400	6	5,600
Total	26	14,500	59	53,800

Mr. Mushet, writing some years later, gives the quantity of charcoal necessary to produce a ton of pig iron as 2,422 lbs.; and reliable authorities estimate the quantity of coal used in the year 1788 in smelting the 53,800 tons of coke pig iron, to have been from 376,000 to 400,000 tons, giving an average of between 7 and 8 tons of coal to each ton of iron made.

TABLE III.

When in the year 1796 previously referred to, Mr. Pitt proposed to levy a tax on coal at the pit's mouth, a formidable opposition was offered to the measure, and an independent inquiry was instituted by our ironmasters, who strongly resisted the proposed impost. The House of Commons appointed a committee of inquiry into the project, the result being the abandonment of the measure. The annexed summary gives the number of furnaces and the make of the several iron making districts at that period:—

SUMMARY OF PIG IRON PRODUCTION IN THE YEAR 1796.

Districts.	Furnaces.	Pig Iron.
	Nos.	Tons. Cwts.
North Staffordshire	2	1,958 10
Cumberland	2	565 0
Derbyshire	12	9,656 0
Gloucestershire	2	380 0
Herefordshire	4	1,749 0
Lancashire	3	2,249 0
Yorkshire	13	10,398 0
Shropshire	23	32,969 10
Sussex	1	173 0
South Wales	24	34,101 0
Mid Wales	1	150 0
North Wales	5	1,144 0
West Wales	1	290 0
South Staffordshire	14	13,210 10
Scotland (coal)	15	15,186 0
,, (charcoal)	2	900 0
Total	124	125,079 10

Detailed particulars of this important return, of which the above is a summary, giving the names of the furnaces, the counties in which situated, and the annual make of pig iron, appear in Table IV.

In this table is indicated the division and the names of all the furnaces in Great Britain in 1796, with the Excise return of the quantity of pig iron made, the quantities supposed and calculated upon by Mr. C., Mr. G., and Mr. W., and the returns of the quantities really made:—*

* Dr. H. G. Macnab. "Observations, &c., on the Coal and Iron Trades, 1796." P. 47. Published 1801.

TABLE IV.

PIG IRON PRODUCTION IN THE YEAR 1796.

Name of Furnace.	What Division.	Excise Return.	Supposed Quantities.	Exact Return.	
		Tons.	Tons.	Tons.	Cwts.
Apedale	Chester	2,100	1,000	728	10
Silverdale	,,	2,600	1,200	1,230	0
Bearpot	Cumberland	2,080	1,200	240	0
Dudden	,,	1,664	400	325	0
Newland	,,	700	700	700	0
Backbarrow	,,	700	700	769	0
Dale Abbey . . .	Derby	474	474	443	0
Morley Park . . .	,,	728	728	728	0
Butterly	,,	936	936	936	0
Flaxley	Gloucester	360	360	360	0
Forest of Dean . .	,,	20	20	20	0
Abry Tinton . . .	Hereford	70	70	70	0
Bishopwood . . .	,,	500	500	947	0
Cornbrook	,,	1,000	1,000	482	0
Brigwood	,,	500	500	250	0
Leighton	Lancaster	780	780	780	0
Bowling (2) . . .	Leeds	2,000	2,000	2,000	0
Wibsey Moor (2) . .	,,	2,000	2,000	2,500	0
Shelf	,,	1,000	1,000	1,140	0
Birkenshaw	,,	780	780	846	0
Renishaw (2) . .	Lincoln	500	500	705	0
Old Park (3) . . .	Salop	11,332½	6,240	5,952	0
Horsehay	,,	4,927½	2,080	1,458	4
Lightmoor (3) . . .	,,	8,946	6,240	2,498	15
Coalbrookdale (3) . .	,,	7,175	4,160	2,659	11
Madeley Wood . . .	,,	3,777½	2,080	1,856	8
Jackfield (2) . . .	,,	7,086	4,160	1,820	0
Benthal	,,	2,367½	1,600	1,334	0
Willey	,,	3,702½	1,600	1,554	10
Broseley	,,	1,775	1,400	1,076	10
Ketley (3)	,,	7,590	6,240	5,068	19
Snedhill (2)	,,	4,730	3,400	3,367	10
Donnington Wood (2) .	,,	4,720	4,160	3,323	0
Chesterfield	Sheffield	940	940	940	0
Little Brampton (2) . .	,,	1,800	1,800	1,560	0
Wingerworth . . .	,,	1,274	1,274	1,274	0
Staveley	,,	1,000	1,000	761	0
Park	,,	1,092	1,092	853	0
Chappel	,,	1,456	1,456	1,456	0
Horncliffe (2) . .	,,	1,092	1,092	712	0
Elsecar	,,	800	800	950	0
Brelton	,,	250	250	250	0
Holmes (3)	,,	6,000	6,000	2,000	0
Carried forward .	. . . .	105,325½	75,912	58,924	17

PIG IRON PRODUCTION IN THE YEAR 1796—*continued.*

Name of Furnaces.	What Division.	Excise Returns.	Supposed Quantities.	Exact Return.	
		Tons.	Tons.	Tons.	Cwts.
Brought forward	. . .	105,325½	75,912	58,924	17
Ashburnham	Sussex	172¼	173	173	0
Clydach	South Wales	1,820	1,820	1,625	0
Blaendare (3)	,,	1,404	1,404	1,500	0
Blaenavon	,,	5,460	5,460	4,318	0
Sirhowy	,,	1,820	1,820	1,930	0
Beaufort	,,	1,560	1,560	1,660	0
Penyca or Ebbw Vale	,,	1,560	1,560	397	0
Hirwain	,,	1,400	1,400	1,050	0
Melincourt	,,	648	648	503	0
Ennisygedyr	,,	1,352	1,352	800	0
Neath Abbey (2)	,,	3,120	3,120	1,759	0
Caerfilly	,,	600	600	695	0
Cfarthfa (3)	,,	6,000	6,000	7,204	0
Plymouth	,,	2,000	2,000	2,200	0
Penydarren (2)	,,	4,000	4,000	4,100	0
Dowlais (3)	,,	4,100	5,400	2,800	0
Llanelly	,,	1,664	1,664	1,560	0
Dovey	Mid Wales	200	200	150	0
Ruabon	North Wales	1,560	1,560	1,144	0
Brymbo	,,	884	silent	...	
Brymbo Gate	,,	728	none	...	
Penyvron	,,	1,498	lead work	...	
Pentroben	,,	1,560	,,	...	
Carmarthen	West Wales	1,056	1,056	290	0
Level	Staffordshire	1,560	1,560	1,391	0
Brierly	,,	1,300	1,300	1,046	10
Deepfield (2)	,,	2,600	2,600	2,526	0
Bilston (2)	,,	2,340	2,340	1,429	0
Bradley (3)	,,	3,640	3,000	1,920	0
Graveyard	,,	1,260	1,336	213	0
Dudley Port	,,	1,040	1,040	869	0
Tipton (2)	,,	2,080	2,080	2,203	0
Gospel Oak	,,	...	...	1,613	0
Scotch Furnaces—					
Carron (4)		...	5,200	5,616	0
Wilson's Town (2)		...	2,080	2,080	0
Muirkirk (2)		...	3,120	2,878	0
Eglinton (3)		...	3,640	2,216	0
Dalrymple (2) Addison (2)		...	3,000	2,396	0
Argyle, charcoal		...	1,600	300	0
Bunawe ,,				600	0
Totals	. . .	167,312¼	152,605	125,079	7

Table V.

Production of Pig Iron in the year 1806.

The number of furnaces built and in blast in Great Britain and the production of pig iron in districts are given as follows:—*

Districts.	Furnaces. In.	Furnaces. Out.	Furnaces. Total.	Make of Pig Iron.
	Nos.	Nos.	Nos.	Tons.
England—				
Staffordshire	32	10	42	50,002
Cumberland	4	...	4	1,955
Derbyshire	11	6	17	9,074
Shropshire	30	12	42	54,966
Lancashire	1	2	3	780
Leicestershire	...	1	1	...
Northumberland	2	...	2	2,500
Yorkshire	22	4	26	27,646
Monmouthshire	3	...	3	2,240
Wales—				
North Wales	3	1	4	2,981
South Wales	35	10	45	68,867
Scotland	18	9	27	22,840
Total	161	55	216	243,851

Table VI.

Production of Pig Iron in the years 1823 and 1830.

In the following comparative statement, made by Mr. Frederick Finch, M.P., who undertook the inquiry for the Government, we have the annexed returns. Mr. Finch took a considerable amount of care to obtain correct results, and was aided in the Scotch returns by Mr. Scudamore:—

Districts.	Furnaces. 1823.	Furnaces. 1830.	Pig Iron Made. 1823.	Pig Iron Made. 1830.	Increase since 1823.
	Nos.	Nos.	Tons.	Tons.	Tons.
Northumberland and Durham . .	2	4	2,379	5,327	2,948
Yorkshire	26	27	27,311	28,926	1,615
Derbyshire	15	18	14,038	17,999	3,961
Shropshire	38	48	57,923	73,418	15,495
Staffordshire	84	123	133,590	211,604	78,014
South Wales	72	113	182,325	277,643	95,318
North Wales	7	12	13,100	25,000	11,900
Scotland	22	27	24,500	37,500	13,000
Total . . .	266	372	455,166	677,417	222,251

The above figures show the average make per furnace in 1823 to have been 1,730 tons, compared with 1,824 tons in the year 1830, and an increase in production between the two years of 222,251 tons, equivalent to 49 per cent.

* Parliamentary Return.

TABLE VII.

PRODUCTION OF PIG IRON IN THE YEAR 1839.

Mr. Mushet, in his papers on Iron and Steel, gives the following as the number of furnaces and the production of pig iron in each district in Great Britain in 1839, to which is added the average make per furnace:—

Districts.	Furnaces.			Pig Iron Made.	Average per Furnace.
	In.	Out.	Building.		
	Nos.	Nos.	Nos.	Tons.	Tons.
South Wales . . .	122	5	32	453,880	3,802
Forest of Dean . . .	5	3	2	18,200	3,640
Shropshire . . .	29	5	...	80,940	2,791
Staffordshire, North . .	7	3	3	18,200	2,600
Staffordshire, South .	120	106	...	346,213	2,885
North Wales . . .	13	7	...	33,800	2,600
Derbyshire . . .	14	2	2	34,372	2,455
Yorkshire.	24	5	...	52,416	2,175
Durham and Northumberland . .	5	...	...	13,000	2,600
Scotland	54	6	18	196,560	3,621
,, (charcoal) .	1	...	...	400	400
Lancashire, ,, . .	2	...	...	800	400
Total . . .	396	142	57	1,248,781	3,153

The make of pig iron in 1839 exceeded that of 1830 by 570,364 tons, equivalent to an increase in the ten years of 84 per cent.

TABLE VIII.

PRODUCTION OF PIG IRON IN THE YEAR 1840.

Previous to the discovery by Neilson of the application of the hot blast, about the year 1829, which was successfully carried out at the Clyde Ironworks, 8 tons of coal previously coked were required to make each ton of pig iron, but by heating the air to a temperature of 300° Fahr. before its introduction into the blast furnace, 5 tons 2 cwts 2 qrs. of coal, converted into coke, were sufficient, and the temperature of the blast being increased to 600°, it was found that raw uncoked coal could be used advantageously. A very important inquiry bearing on the consumption of fuel, instituted by Mr. William Jessop, of the Butterley Ironworks, Derbyshire, led to the fact that in the year 1840, of the 490 furnaces then existing in Great Britain, 402 were in blast, and produced 1,396,400 tons of pig iron with a consumption of 4,877,000 tons of coals. The details of Mr. Jessop's return are as follows:—

Districts.	Furnaces. Built.	Furnaces. In Blast.	Pig Iron Made.	Coal Used.	Coal Used per Ton of Iron. Tons.	Cwts.	Qrs.
	Nos.	Nos.	Tons.	Tons.	Tons.	Cwts.	Qrs.
Forest of Dean .	4	4	15,500	60,000	3	17	2
South Wales . .	163	132	505,000	1,436,000	2	16	3
North Wales . .	15	12	26,500	110,000	4	4	2
Northumberland .	6	5	11,000	38,500	3	9	0
Yorkshire . .	32	25	56,000	306,500	5	9	0
Derbyshire. . .	18	13	31,000	129,000	4	3	0
North Staffordshire.	16	7	20,500	83,000	4	1	0
South Staffordshire.	135	116	407,150	1,582,000	3	17	3
Shropshire . .	31	24	82,750	409,000	4	19	3
Scotland . . .	70	64	241,000	723,000	3	0	0
Total . .	490	402	1,396,400	4,877,000	3	10	0

When Mr. Jessop made his inquiry it was ascertained that of the 402 furnaces in operation 162 were using hot blast, the remaining 240 cold blast. The high rate of consumption of coal in many of the districts, notably those of Yorkshire and Shropshire, being due to the use of the cold blast.

Comparing the above return with that of the previous year, an increase of production is shown of 147,619 tons, equal to nearly 12 per cent.; the average make of the furnaces being 3,473 tons, compared with 3,153 tons.

Table IX.

Production of Pig Iron in the years 1843 and 1847.

With the general depression of trade between the years 1840 and 1845 a great falling off appears, amounting in the year 1843 to 181,050 tons, compared with the production of 1840. It was about the year 1843 that the great extension of our railway system set in, causing a good demand for iron of all kinds, and better prices. To compare the extent of production at this most eventful period in the history of the trade of the country, the returns of the year 1840 are given for comparison with those of 1843 and 1847:—

Districts.	1840. Pig Iron.	1843. Pig Iron.	1847. Pig Iron.
	Tons.	Tons.	Tons.
Derbyshire	31,000	25,750	95,160
Forest of Dean . . .	15,500	8,000	...
North Staffordshire . .	20,500	21,750	65,520
Northumberland . . .	11,000	25,750	99,840
Shropshire	82,750	76,200	88,400
South Staffordshire . . .	407,150	300,250	320,320
North Wales	26,500	19,750	16,120
South Wales	505,000	457,350	706,680
Yorkshire	56,000	42,000	67,600
Scotland	241,000	238,550	539,968
Total	1,396,400	1,215,350	1,999,608

Thus it will be seen that between 1843 and 1847 the iron industries of Great Britain bounded forward at a rapid pace, the increased production in four years amounting to 784,258 tons, equal to 65 per cent.

Table X.

Production of Pig Iron in the year 1852.

Braithwaite Poole in his "Statistics of Commerce," gives the annexed statement of the furnaces in Great Britain in the year 1852, with the make of pig iron, which is supplemented by the average make per furnace in each district:—

Districts.	Furnaces. In.	Furnaces. Out.	Furnaces. Total.	Pig Iron Made.	Average per Furnace.
	Nos.	Nos.	Nos.	Tons.	Tons.
Scotland	113	31	144	775,000	6,860
South Wales . . .	135	27	162	635,000	4,705
,, (anthracite)	12	23	35	31,000	2,583
South Staffordshire .	127	32	159	725,000	5,708
North Staffordshire . .	17	4	21	90,000	5,294
North Wales . . .	6	7	13	30,000	5,000
Shropshire . . .	27	13	40	120,000	4,444
Durham	7	6	13	35,000	5,000
Northumberland . .	18	8	26	110,000	6,111
Yorkshire and Derbyshire . . .	35	7	42	150,000	4,285
Total . . .	497	158	655	2,701,000	5,440

Comparing the above return with that of 1847, when of the 623 furnaces in Great Britain, 433 were in blast, producing 1,999,608 tons of pig iron, or an average of 4,618 tons per furnace; there appears an increase in production of 701,392 tons, equivalent to nearly 36 per cent., and an increase per furnace of 822 tons, the furnaces of smallest capacity being those employing anthracite in South Wales.

Table XI.

Production of Pig Iron between the years 1854 and 1880,

*Showing the Number of Furnaces Built and in Blast in Great Britain, the Production of Pig Iron, and the Average Make per Furnace in each Year.**

Year.	Furnaces.		Pig Iron Made.	Average per Furnace.
	Built.	In Blast.		
	Nos.	Nos.	Tons.	Tons.
1854	724	555	3,069,838	5,530
1855	763	589	3,218,154	5,463
1856	785	622	3,586,377	5,766
1857	823	628	3,659,447	5,829
1858	833	617	3,456,064	5,600
1859	862	607	3,712,904	6,116
1860	872	582	3,826,752	5,575
1861	852	569	3,712,390	6,524
1862	876	561	3,943,469	7,029
1863	908	597	4,510,040	7,554
1864	883	612	4,767,951	7,790
1865	919	656	4,825,254	7,355
1866	839	618	4,523,897	7,320
1867	818	551	4,761,023	8,640
1868	912	560	4,970,206	8,873
1869	901	600	5,445,757	9,076
1870	916	664	5,963,515	9,000
1871	897	673	6,627,179	9,847
1872	876	702	6,741,929	8,604
1873	892	683	6,566,451	9,613
1874	915	649	5,991,408	9,232
1875	899	629	6,365,462	10,120
1876	927	585	6,555,997	11,106
1877	940	541	6,608,664	12,215
1878	948	498	6,381,051	12,813
1879	929	496	5,995,337	12,090
1880	926	567½	7,749,233	13,679

* "Mineral Statistics of the United Kingdom."

TABLE XII.

PIG IRON EXPORTED FROM THE UNITED KINGDOM IN EACH YEAR SINCE 1829:—

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1829	8,931	1855	291,776
1830	12,036	1856	357,326
1831	12,444	1857	422,086
1832	17,566	1858	360,425
1833	22,988	1859	316,376
1834	21,788	1860	342,567
1835	33,073	1861	388,004
1836	33,880	1862	444,708
1837	44,387	1863	466,423
1838	48,554	1864	465,985
1839	43,460	1865	547,641
1840	49,801	1866	500,500
1841	85,866	1867	565,612
1842	93,851	1868	552,999
1843	154,770	1869	710,656
1844	99,960	1870	753,339
1845	77,362	1871	1,061,004
1846	159,163	1872	1,331,143
1847	176,086	1873	1,142,065
1848	175,650	1874	774,280
1849	161,775	1875	947,227
1850	141,973	1876	910,005
1851	201,264	1877	881,442
1852	240,491	1878	923,080
1853	333,585	1879	1,223,436
1854	293,432	1880	1,631,629

TABLE XIII.

PIG IRON EXPORTED FROM THE UNITED KINGDOM.

Showing Countries to which exported and Value of Exports for the Three Years ending 1880:—

Countries to which Exported.	QUANTITIES.			VALUE.		
	1878.	1879.	1880.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	£	£	£
Russia . .	85,509	146,830	152,966	253,036	412,830	503,317
Germany . .	228,434	233,900	247,874	591,350	517,328	635,771
Holland . .	240,969	213,386	190,026	674,892	547,170	600,926
Belgium . .	90,318	83,750	116,628	221,902	194,230	342,417
France . .	96,363	85,520	99,036	223,175	184,690	251,961
United States .	32,663	277,939	612,013	133,008	873,320	2,278,916
British North America .	23,423	29,820	54,748	69,016	79,360	177,421
Other countries	125,401	152,291	158,338	303,803	341,461	416,545
Totals .	923,080	1,223,436	1,631,629	2,470,182	3,150,389	5,207,294

APPENDIX.—No. 3.

MALLEABLE IRON WORKS (MILLS AND FORGES) AND STEEL WORKS.

TABLE I.

MILLS AND FORGES.

Quantities of Bar Iron made in each county in England and Wales in the year 1750.*

Counties.	Quantities.	Counties.	Quantities.
	Tons.		Tons.
Breconshire	350	Brought forward	7,180
Caermarthenshire	480	Monmouthshire	2,000
Cardiganshire	120	Montgomeryshire	200
Cheshire	640	Nottinghamshire	370
Denbighshire	280	Northumberland	120
Derbyshire	640	Pembrokeshire	240
Durham	250	Shropshire	2,260
Flintshire	200	Surrey and Kent	...†
Gloucestershire	1,120	Sussex	...†
Glamorganshire	1,100	Staffordshire	1,990
Herefordshire	1,000	Warwickshire	300
Hampshire	250	Worcestershire	1,580
Lancashire	750	Yorkshire	2,560
Carried forward	7,180	Total	18,800

* For number of Forges in each county and production of bar iron see Table II.

† Quantities not ascertained.

Table II.

"*A* List *of the* Forges *in* England *and* Wales *in* 1750; *with an account of the quantity of* Bar-iron *they make annually according to the best information that could be got on a strict inquiry, blanks being left for the quantity made yearly at different places, whereof we could not have a certain account. The* Forges *in* Scotland *are not included.*"

The original document of which this is a copy, is in the possession of Samuel Timmins, Esq., of Elvethan Lodge, Birmingham, who courteously placed it at the service of the author for publication.

	Tons.
Breconshire.	
Tanner's Forge	150
Llanelly	200
Caermarthenshire.	
Kidwelly	100
Whitland	100
Cymdwyfran	120
Cambrayne	60
Lannovaine	100
Cardiganshire.	
Lanfrede	120
Cheshire.	
Cranage	200
Warmingham	300
Lea	140
Denbighshire.	
Pontablue	200
Wrexham	80
Derbyshire.	
Barton Fields	120
New Mills	250
Plesley	150
Staveley	120
Durham.	
Winlaton, Swallwell, Teams	250
Flintshire.	
Badvary	200
Gloucestershire.	
Lidney	350
Lidbrooke, Three Forges	350
Upleadon	120
Tortworth	150
Flaxley	150
Carried Forward	4,080

	Tons.
Brought Forward	4,080
Glamorganshire.	
Forrest	200
Aberavan	350
Velin Griffy's	300
New Forge	250
Herefordshire.	
New Weare	350
Bringwoode	450
Landiloe	200
Hampshire.	
Sowley	50
Tichfield	200
Lancashire.	
Cunsey	120
Backbarrow	260
Sparke Bridge	120
Coniston	80
Caton	50
Burgh	120
Monmouthshire.	
Malion and Tredegar, Three Forges	600
Pont Pool	700
Tuiton, Two Forges	300
Monmouth	400
Montgomeryshire.	
Mattravil	200
Dolobran	...
Nottinghamshire.	
Bulwell	150
Carburton	220
Clipton	...
Cuckney	...
Carried Forward	9,750

A LIST *of the* FORGES *in* ENGLAND *and* WALES *in* 1750—*continued.*

	Tons.
Brought Forward	9,750
NORTHUMBERLAND.	
Darwincoat	120
PEMBROKESHIRE.	
Blackpoole	240
Coiducore is rebuilding	...
SHROPSHIRE.	
Cloebury	250
Longnor	140
Upton	260
Colebrookdale	150
Witheford	250
Sutton	260
Tern	150
Kaynton	250
Norton	150
Winnington	100
Prescot	100
Lizard	200
SURREY AND KENT.	
Touchley	...
Barden	...
Mr. Johnston's	...
Mr. Gale's	...
Mr. Dibble's	...
Shingley	...
Pophole	...
SUSSEX.	
Bivelham	...
Hawkesden	...
Brightlin	...
Burwash	...
Westfield	...
Marshfield	...
Woodcock	...
Carried Forward	12,370

	Tons.
Brought Forward	12,370
STAFFORDSHIRE.	
Consall	300
Hints	250
Cannock	180
Bromwiche	300
Little Aston	100
Corngreve	120
Coven	100
Heath	200
Whittington	300
Swiner	140
WARWICKSHIRE.	
Bromford	300
Clifford	...
WORCESTERSHIRE.	
Shellery	350
Wildon	450
Jennypole	450
Lower Milton	400
Woolverley	300
Cookley	300
Cradley and Lye	160
Powick	150
YORKSHIRE.	
Attercliffe	260
Colnbridge	150
Kirkstall	160
Waddesley	200
Kilnhurst	220
Wortley	350
Roach Abbey	60
Mousehole	60
Seamore	120
Total	18,800

Table III.

Malleable Iron Works.

Showing the Number of these Works, the Number of Puddling Furnaces and Rolling Mills in Great Britain in each year since 1861.

Year.	Number of Works.	Number of Puddling Furnaces.	Number of Rolling Mills.
1861	213	4,147	439
1862	217	4,832	647
1863	223	5,013	654
1864	248	6,338	705
1865	252	6,407	730
1866	256	6,239	826
1867	254	6,009	831
1868	247	5,903	831
1869	245	6,243	859
1870	255	6,699	851
1871	267	6,841	866
1872	276	7,311	1,015
1873	287	7,264	939
1874	298	6,803	866
1875	314	7,575	909
1876	312	7,159	942
1877	300	6,796	935
1878	232	5,125	830
1879	314	5,149	846
1880	314	5,134	855

Table IV.

Bessemer Steel Works.

List of Works *in Great Britain in the Year* 1880, *giving the Number of Convertors and their Capacity.*

No.	Name and Situation of Works.	Number of Convertors.	Capacity of Convertors. Tons. Cwts.
1	Bessemer, Henry and Co., Sheffield	2 2	3 0 5 0
2	Bolckow, Vaughan and Co., Limited	4 2	8 0 15 0
3	Brown, John and Co., Limited, Sheffield	4 2	7 10 10 0
4	Brown, Bayley, and Dixon, Limited, Sheffield Steel and Iron Works	2 4	4 0 8 0
5	Cammel, Charles and Co., Limited, Cyclops Works, Sheffield	4	4 0
6	Cammel, Charles & Co., Limited, Yorkshire Works, Sheffield	2 2	5 0 7 0
7	Weardale Iron Co., Tudhoe, Ferryhill	2	2 10

TABLE IV.—*continued.*

No.	Name and Situation of Works.	Number of Convertors.	Capacity of Convertors.
			Tons. Cwts.
8	Glasgow, The, Bessemer Steel Co., Limited, Atlas Works, Glasgow	2	3 0
9	Fox, Samuel and Co., Stockbridge Works, Sheffield	2	5 0
10	Patent Shaft and Axletree Co., Limited, Monway Works, Wednesbury	4	3 0
11	Bolton Iron and Steel Co., Limited, Bolton, Lancashire	4	5 0
12	London and North Western Railway Co., Crewe Works, Cheshire	2	3 0
13	Manchester, Sheffield, and Lincolnshire Railway Co., Gorton Works, Manchester	4	3 0
14	Mersey Iron and Steel Works, Toxteth Park, Liverpool	8	5 0
15	Manchester Steel and Railway Plant Co., Gibraltar Works, Newton Heath, Manchester	4	3 0
16	Barrow Hematite Steel Co., Barrow Works, North Lancashire	8	7 0
17	Dowlais Iron Co., Dowlais Works, Glamorganshire	2 2 2	7 10 6 0 5 0
18	West Cumberland Iron and Steel Co., Workington	2 2	8 0 6 0
19	Steel, Tozer, & Hampton, Limited, Phœnix Works, The Ickles, near Sheffield	2 2 2	8 0 4 0 2 0
20	Carnforth Hematite Iron Co., Limited, Carnforth, Lancashire	2	6 0
21	Muller, Charles Emile, Erimus Steel Works, Middlesborough	2	6 0
22	Darlington Iron Co., Darlington	2	...
23	Moss Bay Hematite Iron and Steel Co., Workington, Cumberland	3	8 0
24	Rhymney Iron Co., Monmouthshire	3	7 0
25	Blaenavon Iron and Steel Co., Blaenavon, Monmouthshire	2	8 0
26	The Standard Iron and Steel Co.	2	...
27	Ebbw Vale Co., Ebbw Vale, Monmouthshire	4 2	8 0 10 0

TABLE V.

PRODUCTION OF BESSEMER STEEL *in Great Britain in each year since* 1871.

Year.	Bessemer Steel.	Year.	Bessemer Steel.
	Tons.		Tons.
1871	329,000	1876	700,000
1872	410,000	1877	750,000
1873	496,000	1878	807,527
1874	540,000	1879	834,511
1875	620,000	1880	1,044,382

TABLE VI.

PRODUCTION OF BESSEMER STEEL *in each district in Great Britain in the years* 1879 *and* 1880.*

District.	1879. Bessemer Steel.	1880. Bessemer Steel.
	Tons.	Tons.
South Wales . . .	252,573	308,233
Sheffield	210,346	273,365
Lancashire . . .	152,130	167,870
Cumberland . . .	127,163	140,869
North East Coast . .	85,299	144,000
Staffordshire . . .	7,200	10,045
Total. . .	834,711	1,044,382

TABLE VII.

SIEMENS' STEEL WORKS.

LIST OF FIRMS *who are manufacturers of Steel by the Open-Hearth Steel Melting Process, with the number of Furnaces erected by each.*

NAME AND SITUATION OF WORKS.	NO. OF FURNACES.
The Landore Siemens Steel Co., Limited, Landore .	24
Messrs. Vickers, Sons, and Co., Limited, Sheffield . .	10
The Steel Co. of Scotland, Limited, Glasgow . . .	20
Sir Joseph Whitworth and Co., Limited, Manchester .	5
The Panteg Steel Works and Engineering Co. . .	13
The London and North Western Railway Co., Crewe .	5
The Bolton Iron and Steel Co., Limited, Bolton . .	3
Messrs. Charles Cammell and Co., Sheffield . . .	6
Messrs. John Spencer and Sons, Newcastle . . .	2
The Dowlais Iron Co., Dowlais, Glamorganshire . .	6
The Bowling Iron Co., Limited, Bradford . . .	2
The Railway Steel and Plant Co., Limited, Manchester	2
The Butterley Co., Alfreton, Derbyshire	3
Sir John Brown and Co., Limited, Sheffield . . .	1
The Albion Steel and Wire Co., Limited, Sheffield . .	2
Messrs. Wright Buller and Co., Elba Steel Works, near Swansea	4
Messrs. White and Challingsworth, Pontymister, Newport, Monmouthshire	1
Messrs. E. Morewood and Co., Llanelly, Glamorganshire	2
Messrs. W. and T. Beardmore, Glasgow	5
Messrs. John Williams and Co., Wishaw	3
Mr. James Butler, Middlesborough-on-Tees . . .	1

* "British Iron Trade Association," Report, 1880. p. 29.

Table VII.—*continued.*

NAME AND SITUATION OF WORKS.	NO. OF FURNACES.
The Barrow Hematite Steel Co., Limited, Barrow, Lancashire	3
The H. P. Horse Nail Co., Limited, London	1
The Mossend Iron Co., Holytown, N.B.	4
Mr. David Colville, Motherwell, N.B.	4
The West Cumberland Iron and Steel Co., Limited, Workington	2
The Consett Iron Co., Limited, Blackhill	2
The Shotts Iron Co., Carluke, N.B.	1

Table VIII.

Production of Open-Hearth Steel *in Great Britain in the year* 1880 *and seven previous years.**

Year.	Quantities.	Year.	Quantities.
	Tons.		Tons.
1873	77,500	1877	137,000
1874	90,500	1878	175,000
1875	88,000	1879	175,000
1876	128,000	1880	251,000

The details of production, with the number of Open-Hearth Furnaces in each district in the years 1879 and 1880 appear in the following return:—

Table IX.

Production of Open-Hearth Steel *in each district in Great Britain in the years* 1879 *and* 1880:—*

Districts.	Open Hearth Furnaces.		Open Hearth Steel.	
	1879.	1880.	1879.	1880.
	Nos.	Nos.	Tons.	Tons.
South Wales	48	49	85,000	116,000
Scotland	16	36	50,000	84,500
Sheffield	15	19	21,000	23,500
Lancashire and Cheshire	12	14	15,000	19,500
North East Coast . .	5	5	1,000	3,200
Other Districts . . .	6	3	3,000	4,300
Total . . .	102	126	175,000	251,000

* "British Iron Trade Association," Report, 1880, pp. 34, 35.

TABLE X.

LIST OF FIRMS *who employ the* "SIEMENS REGENERATIVE GAS FURNACES" *for melting Steel in Crucibles.*

YORKSHIRE.

Messrs. Vickers, Sons, and Co., Limited, Sheffield.
Messrs. Sanderson Brothers and Co., Limited, Sheffield.
Mr. Robert Marsden, Sheffield.
The Monkbridge Iron Co., Leeds.
The Bowling Iron Co., Limited, Bradford.

LANCASHIRE.

The Bolton Iron and Steel Co., Limited, Bolton.
The Mersey Steel and Iron Co., Limited, Liverpool.
The Steel Casting Co., Limited, Barrow-in-Furness.

CUMBERLAND.

The West Cumberland Iron and Steel Co., Limited, Workington.

STAFFORDSHIRE.

The Patent Shaft and Axle Co., Old Park, Wednesbury.

SHROPSHIRE.

Messrs. Nettlefolds, Limited, Castle Iron Works, Wellington.

DURHAM.

Messrs. John Spencer and Sons, Newcastle-on-Tyne.

MONMOUTHSHIRE.

Ebbw Vale Co., Ebbw Vale, Monmouthshire.

REGENERATIVE GAS HEATING FURNACES.

The Low Moor Works, Bradford.
Carnforth Hematite Iron Co., Carnforth.
Messrs. Samuel Fox and Co., Limited, Sheffield.
Messrs. R. Johnson and Nephew, Bradford, Manchester.

TABLE XI.

PRODUCTION OF CRUCIBLE STEEL *since the year* 1873, *in the Works in Great Britain by the Siemens Regenerative Gas Furnaces.*

Year.	Crucible Steel.	Year.	Crucible Steel.
	Tons.		Tons.
1873	5,900	1877	3,900
1874	3,300	1878	2,980
1875	4,000	1879	2,900
1876	4,150	1880	3,050

Sheffield still continues to be the chief centre of this industry; and it further appears that during the year 1880 nearly 1,500 tons of Steel were made in this locality by a process patented by Mr. W. R. Hadfield and described as a combination of the Bessemer and Siemens processes.*

* "British Iron Trade Association," Report, 1880, p. 37.

APPENDIX.—No. 4.

TIN PLATE MANUFACTURE.

The earliest establishment engaged in this industry appears to have been founded in this country about the year 1720 at Pontypool in Monmouthshire. The art of tinning was early practised in the kingdom of Bohemia in the beginning of the 17th century, it is said about the year 1620, and some years later the art was introduced into the kingdom of Saxony. The art, as previously stated, was introduced into this country about the year 1720; it was not, however, until the year 1728 that any considerable advance was made, when Mr. John Payne invented a process for rolling iron; this appears to have been further supplemented by the grooved mills, invented about the year 1783, by Mr. Henry Cort. Many years, however, passed away before Cort's invention was fully appreciated. Mr. Reynolds, of the Ketley Iron Works, in Shropshire, erected the first of Cort's Rolls, and about the year 1790 Mr. Richard Crawshay erected rolling mills at Cyfarthfa, in Glamorganshire.*

The selection of iron for the making of the various descriptions of tin plate is of the utmost importance, the great tests of quality being ductility, strength, and a peculiar crystalline structure and grain, well known to the tin-plate manufacturer.

The greatest care is taken to reject any plate at all faulty, after it has passed through the various processes necessary in its preparation for tinning. This faulty condition is observed in the passage of the plate through the chilled rolls after being freed from rust, or scale of oxide iron, formed in the previous operations through which the tin plates pass in heating and reheating in the furnace, and cleansing in the acid bath.

In the process of tinning, Dr. Percy † says: "About 8 or 8½ lbs. of tin are used on an average per box of tin plates," and that "the quantity of

* The process of manufacture, tin plates, charcoal plates, &c., will be found fully described in Dr. Percy's Metallurgy, "Iron and Steel," p. 725.

† *Ibid.* p. 729.

mixed metal for terne plates will vary from 10 lbs. to 14 lbs., according to the proportions of lead employed; this last-named variety of tin plates, called "terne plates," are coated with an alloy of tin and lead, the surface being dull compared with that of tin plates. Terne plates are exported in considerable quantities to Canada where they are in great request for roofing. The standard of quotation is always taken at 1C (Common No. 1); this is a box containing 225 plates, 13¾ inches by 10 inches, which should weigh 1 cwt. or 112 lbs.

Table I.

Production of Tin, Terne and Black Plates in Great Britain.

The year 1870 furnishes the earliest information on the subject: 57 works were then in operation in Great Britain, more or less actively employed; of these 33 furnished returns amounting to 199,782 boxes weighing 81,477 tons, the total production the same year amounting to 3,459,782 boxes. In subsequent years the number of works were as follows, the actual returns being distinguished from those estimated, these latter quantities being arrived at by gentlemen connected and intimately acquainted with the tin plate manufacture:—

Year.	No. of Works.	Boxes Returned.		Boxes Estimated.	Total Number of Boxes.
		Number.	Weight.		
		Nos.	Tons.	Nos.	Nos.
1871	57	1,444,087	83,917	949,204	2,393,291
1872	61	1,534,181	78,088	1,443,670	2,977,851
1873	69	1,974,989	116,943	710,056	2,685,045
1874	69	1,204,576	62,268	1,325,000	2,529,576
1875	68	1,601,516	82,490	1,350,600	2,952,116
1876	68	1,646,276	85,472	1,170,117	2,815,393
1877	75	1,788,549	86,738	2,261,201	4,049,750
1878	75	2,257,791	109,183	1,800,209	4,058,000
1879	78	2,631,166	117,970	1,619,179	4,250,345
1880	97	3,390,647	158,925	2,609,353	6,000,000

In the year 1879, the 78 works engaged in the various forms of tin plate possessed 264 mills; of these 222 were in operation, producing 4,250,345 boxes, the total weight being 190,576 tons, the average weight of each box being nearly 1 cwt.; while it was in the same year estimated by the highest authority in the trade, that, had the works been in full activity during the year, they were capable of producing 6,854,740 boxes.

Table II.

Summary of Tin Plate Works in Great Britain in the Year 1880:—*

Counties.	No. of Works.	Mills Built.
Glamorganshire	45	188
Caermarthenshire	14	65
Monmouthshire	17	63
Gloucestershire	6	18
Staffordshire and Worcestershire .	11	31
Scotland	2	5
Cumberland	1	5
Flintshire	1	2
Total	97	377

The details of returns received from tin plate works for the year 1880 have been as follows:—

	Boxes.
Number of boxes of tin and terne plates	2,478,742
,, of boxes of black plates	911,905
Total number of boxes	3,390,647

Actual weight of the whole returned, 158,925 tons.

The tin plate works which have not made returns are estimated as follows:—

	Boxes.
The *estimated number* of boxes of tin, terne, and black plates	2,609,353
Actual number of boxes of tin, terne, and black plates *returned* as above	3,390,647
Total number of tin, terne, and black plates, made in the United Kingdom in the year 1880	6,000,000

The total estimated weight of the whole, 237,084 tons.

* Mineral statistics of the United Kingdom.

Table III.

Glamorganshire.

The annexed Table presents a Complete List *of the* Tin Plate Works *of* Great Britain *at the present time*, 1880:—

Name of Works.	Name of Firm.	Total Mills.
Aberdulais (Neath) . . .	Joshua Williams & Co., Limited	5
Amman (Bryn Amman) . .	Amman Iron Co. . . .	4
Avon Vale (Aberavon) . .	Port Talbot Tin Plate Co. .	4
Beaufort (Morriston) . .	Beaufort Tin Plate Co. . .	7
Burrows (Taibach) . . .	Glamorgan Tin Plate Co. .	3
Cambria (Pontardulais) . .	Cambria Co-operative Co. . .	1
Cilfrero (Neath)	Prosser Son & Co., Limited .	2
Clydach (Swansea) . . .	John Player	2
Clyne (Neath)	H. Thomas & Co., Limited .	2
Cwm Avon (Taibach) . .	Copper Miners' Tin Plate Co. .	8
Cwm Bwrla (Swansea) . .	Swansea Tin Plate Co. . .	5
Cwm Felin (Swansea) . .	Cwm Felin Tin Plate Co. Lmtd.	5
Dowlais (Merthyr) . . .	Dowlais Iron Co.	2
Dyffryn (Morriston). . .	Daniel Edwards and Co. . .	6
Foxhall (Llansamlet) . . .	Foxhall Tin Plate Co. . .	2
Gadlys Uchaff (Cardiff) . .	Hosgood & Smith . . .	3
Glamorgan (Pontardulais) . .	Webb, Shakespear, & Williams	2
Glantawe (Swansea) . .	Glantawe Tin Plate Co. . .	2
Glanyrafon (Swansea) . .	Glanyrafon Iron & Tin Plate Co.	2
Gorceinon (Swansea) . .	Gorceinon Tin Plate Co. . .	2
Gower (Penclawd) . . .	Morris, Smith, Thomas & Co. .	4
Gurnos (Ystalyfera) . .	Gurnos Tin Plate Co. . .	2
Landore (Swansea) . . .	Landore Tin Plate Co. . .	7
Llantrissant (Cardiff) . .	Llantrissant Tin Plate Co. .	4
Llwydarth (Maesteg) . . .	Llwydarth Tin Plate Co. . .	5
Mansel (Taibach) . . .	Mansel Tin Plate Co. . .	6
Margam (Neath) . . .	Robert B. Byass & Co. . .	6
Melyn Griffith (Cardiff) . .	T. W. Booker & Co., Limited .	6
Melyn (Neath)	Leach, Flower, & Co. . . .	7
Merthyr (Aberdare) . .	Stuart Steel, Iron, & Tin Plate Co.	2
Midland (Morriston) . . .	D. Glasbrook & Co. . .	3
Morriston (Swansea) . .	Morriston Tin Plate Co. . .	5
Pontardawe (Swansea) . . .	W. Gilbertson & Co. . . .	6
Pontardulais (Pontardulais) .	Pontardulais Tin Plate Co. .	3
Taibach (Port Talbot) . . .	D. R. David & Co. . . .	2
Teilo (Pontardulais). . .	Teilo Tin Plate Co. . . .	2
Treforest (Pontypridd) . .	Treforest Tin Plate Co. . .	5
Upper Forest (Swansea) . .	Llansamlet Tin Plate Co. .	7
Vernon (Breton Ferry) . .	David Morris & Co. . . .	8
Waterloo (Cardiff) . . .	George Geen & Co. . . .	2
Worcester (Swansea) . . .	Llansamlet Tin Plate Co. . .	5
Ynismendwy (Swansea) . .	Ynismendwy Tin Plate Co. .	2
Ynispenllwch (Clydach) . .	Tawe Tin Plate Co., Limited .	5
Yspitty (Loughor R. S. O.) .	J. Rushton Turnock . .	3
Ystalyfera (Swansea) . . .	Ystalyfera Iron Co. . . .	12
Total of Glamorganshire		188

Table IV.

Caermarthenshire.

Name of Works.	Name of Firm.	Total Mills.
Avondale	Avondale Iron and Tin Plate Co.	1
Burry (Llanelly) . . .	Burry Tin Plate Co., Limited .	4
Caermarthen (Caermarthen) .	Thomas Lester & Co. . .	5
Dafen (Llanelly). . . .	Phillips, Nunes, & Co. . .	4
Glanamman (Cwmamman) .	Glanamman Tin Plate Co., Lim.	2
Gwendraeth (Kidwelly) . .	J. Chivers & Son . . .	10
Hendy (Pontardulais) . .	Edm. Boughton & Co., Limited	4
Lion	H. Thomas	2
Llanelly (Llanelly) . . .	John S. Tregonning & Son .	4
Llangennech (do.) . . .	Llangennech Tin Plate Co. . .	8
Morlais (Llangennech) . .	Llansamlet Tin Plate Co. .	2
Old Castle (Llanelly) .	Old Castle Iron and Tin Plate Co., Limited. . . .	6
South Wales (Llanelly) . .	E. Morewood & Co. . . .	9
Western (Llanelly) . . .	Western Tin Plate Co., Limited	4
Total of Caermarthenshire		65

Table V.

Monmouthshire.

Name of Works.	Name of Firm.	Total Mills.
Abergavenny (Abergavenny) .	Llanelly Iron and Tin Plate Co.	2
Abercarne (Newport) . .	Daniel Whitehouse . . .	8
Abertillery (Newport). . .	Philip S. Phillips . . .	7
Blaina (Blaina) . . .	Blaina Iron and Tin Plate Co. .	6
Caerleon (Newport) . . .	F. Moggridge & Co. . .	2
Garth (Newport). . . .	Garth Iron and Tin Plate Co. .	4
Machen (Newport) . . .	Machen Iron and Tin Plate Co.	3
Monmouth Forges . . .	H. T. Griffiths & Co. . . .	1
Pontnewydd (Newport) . .	B. Conway & Co. . . .	2
Pontrhydyrun (Newport) .	Conway Brothers . . .	2
Pontheer (Caerleon) . . .	Conway, Conway & Co. . .	2
Pontymister (Newport) . .	Pontymister Tin Plate Co. .	5
Pontypool (Pontypool) . .	Pontypool Iron and Tin Plate Co.	8
Redbrook (Monmouth) . .	Redbrook Tin Plate Co. . .	3
Rhiwderin (Newport) . . .	Garth Iron and Tin Plate Co. .	4
Tydu and Rogerston (Newport)	Tydu and Rogerston Tin Plate Co.	2
Tynewydd (Pontnewydd) .	Tynewydd Iron and Tin Plate Co., Limited	2
Total of Monmouthshire		63

Table VI.

Gloucestershire.

Name of Works.	Name of Firm.	Total Mills.
Abbey Tintern (Chepstow) .	Abbey Tintern Wire and Tin Plate Co.	2
Caldicot (Chepstow) . .	Caldicot Tin Plate Co. . .	2
Hawkwell (Cinderford) . .	J. Chivers & Co.	3
Lydney (Lydney) . . .	Richard Thomas & Co. . .	4
Lydbrook (Ross)	Richard Thomas & Co. . .	5
Parkend (Lydney) . . .	Henry Crawshay & Sons . .	2
Total of Gloucestershire		18

Table VII.

Staffordshire and Worcestershire; Scotland, Cumberland, and Flintshire.

Name of Works.	Name of Firm.	Total Mills.
Staffordshire and Worcestershire.		
Bradley (Bilston)	Hatton, Sons, & Co. . .	4
Broadwaters (Kidderminster) .	,, ,, ...	2
Brockmoor (Brierley Hill) . .	Budd and Co.	4
Cookley (Kidderminster) . .	John Knight & Co. . . .	3
Hope (Tipton)	Hope Iron and Tin Plate Co. .	2
Horseley Fields (Wolverhampton)	E. P. and W. Baldwin . .	1
Manor (Wolverhampton) . .	Stephen Thompson . . .	2
Osier Bed ,, ...	Osier Bed Iron Co. . . .	3
Rugeley	David Griffiths & Co. . .	1
Tividale (Tipton)	Budd & Co.	4
Wilden (Stourport)	E. P. and W. Baldwin . .	5
Total of Staffordshire and Worcestershire . . .		31
Scotland.		
Coatbridge (Glasgow) . .	Coatbridge Tin Plate Co., Lim.	3
Milton (Motherwell) . . .	Isaac Summerhill & Co. . .	2
Total of Scotland		5
Cumberland.		
Derwent (Workington) . .	W. Griffiths & Co. . . .	5
Flintshire.		
Mold (Flint)	Alyn Tin Plate Co. . . .	2

TABLE VIII.

EXPORTS OF TIN PLATES *in each of the following years, and Ports from which Exported.*

Ports from which Exported.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.
	Boxes.	Boxes.	Boxes.	Boxes.	Boxes.	Boxes.	Boxes.	Boxes.
Liverpool . .	1,585,012	1,497,440	1,806,737	1,769,313	2,102,620	2,052,932	2,115,632	2,345,247
London . .	251,806	231,262	327,800	310,372	357,159	345,508	397,399	364,268
Swansea . .	73,077	41,456	65,487	108,616	102,721	109,829	134,309	60,162
Bristol . .	63,392	110,471	107,883	125,082	190,469	213,092	603,644	1,032,934
Cardiff . .	41,948	130,224	18,734	982	11,020	88,258	262,064	162,755
Glasgow . .	8,059	4,128	3,472	2,875	2,468	3,823	8,351	14,436
Southampton .	104,804	105,869	96,505	67,244	34,193	5,772	3,970	97,987
Hull . .	12,560	19,562	19,618	10,263	14,157	15,490	7,860	8,476
Newcastle. .	613	1,838	2,470	5,102	4,153	2,698	939	2,836
Newhaven .	12,206	1,218	280	189	120	274	1	59
Total . .	2,153,477	2,143,468	2,448,986	2,400,038	2,819,098	2,837,776	3,534,169	4,089,160

TABLE IX.

Exports of TIN PLATES *(number of Boxes) from the* UNITED KINGDOM *to all Ports, in each of the following years, and Countries receiving the same.*

Countries to which Exported.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.
United States Ports.	1,511,632	1,585,994	1,673,435	1,609,515	1,943,444	1,931,128	2,756,421	2,959,380
Holland, Germany, and Belgium . .	63,647	96,313	129,114	140,165	121,884	149,640	159,362	126,805
Australia and New Zealand . .	76,890	42,394	52,655	69,782	76,855	63,578	42,081	80,855
Italy and Mediterranean . . .	114,699	72,990	121,348	97,379	91,675	141,691	108,977	196,377
Canada and B. N. America . .	69,318	66,188	78,022	95,684	167,592	103,284	120,798	200,138
France and Switzerland . . .	71,589	40,318	63,455	108,752	97,517	97,928	75,311	148,914
South America and Brazils . .	50,852	51,079	54,151	52,586	54,402	62,676	48,537	68,661
Spain and Portugal .	64,041	54,013	72,174	60,994	68,612	70,101	61,225	86,179
Norway, Sweden, and Baltic . .	67,639	71,555	114,993	83,233	88,298	103,008	81,029	93,147
India and China .	42,515	44,636	71,897	61,763	86,369	92,260	63,431	124,554
West Indies . .	8,434	8,953	8,847	10,143	12,891	12,033	9,346	13,626
Cape, Ceylon, and Mauritius . .	7,984	3,111	2,918	4,261	3,174	3,080	3,414	3,718
Africa and Outside Islands . .	3,038	4,169	4,281	3,919	4,478	5,676	4,242	4,504
Unclassed . . .	1,199	1,755	1,696	1,862	1,907	1,693	995	2,802
Total Boxes .	2.153,477	2,143,468	2,448,986	2,400,038	2,819,098	2,837,776	3,534,169	4,089,160

Table X.

Tin Plates Exported.

Countries to which exported, Quantities and Value in each of the years 1870, 1875, *and* 1880 *(according to Trade and Navigation Returns).*

Countries to which Exported.	Quantities.			Value.		
	1870.	1875.	1880	1870.	1875.	1880.
	Tons.	Tons.	Tons.	£	£	£
France	1,258	3,186	4,418	27,135	84,602	82,362
United States . .	75,372	95,995	164,284	1,762,914	2,541,004	3,374,010
British North America	2,982	4,134	10,399	73,740	118,004	221,245
Australia	3,136	3,192	4,474	82,925	91,234	95,723
Other Countries . .	17,329	31,856	34,124	421,843	856,538	674,752
Total . .	100,077	138,363	217,699	2,368,557	3,691,382	4,448,092

INDEX.

THE END.

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